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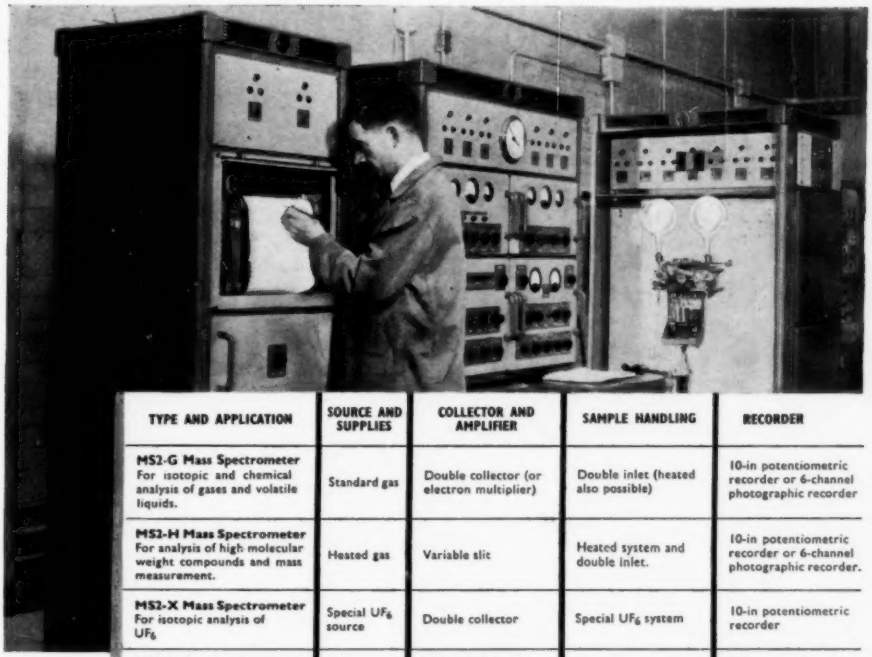

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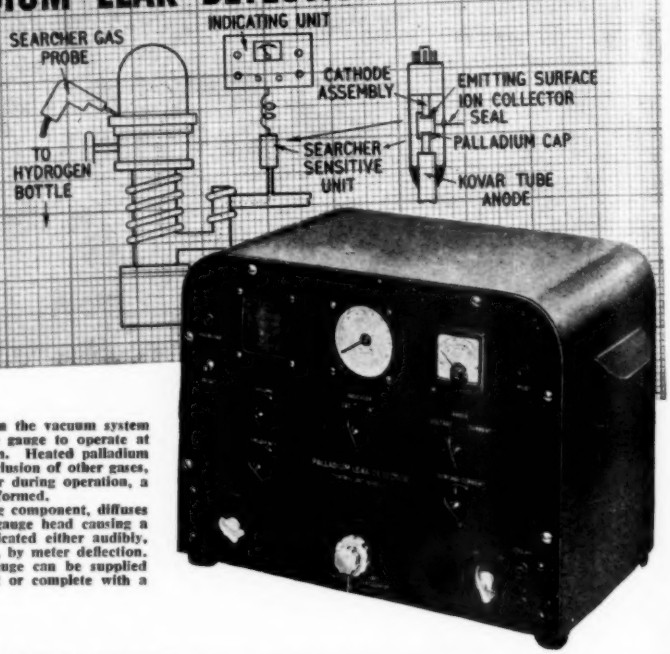

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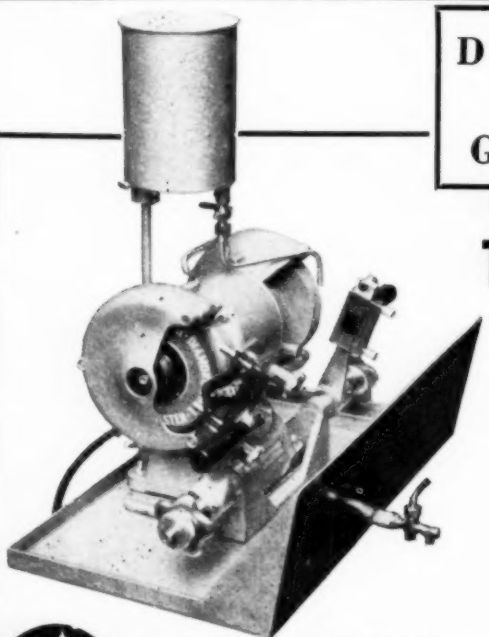

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"Where σ is stress, *p* is density and V is particle velocity . . ."

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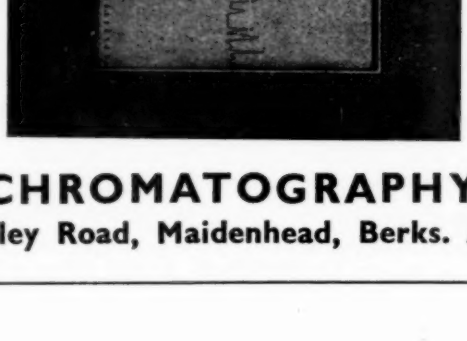

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RESOURCES FOR ATOMIC ENERGY AND SPACE RESEARCH

THE subject of space research has already been discussed three times in the House of Commons during the past two sessions: on a motion by Mr. G. de Freitas in April 1959; on one by Mr. F. V. Corfield last February; and on a motion by Mr. G. de Freitas again on July 29. Between the second and third debates, on April 24, the Parliamentary and Scientific Committee was addressed by Sir Edward Bullard, Prof. W. R. Hawthorne, Sir Robert Cockburn and Dr. D. Taylor, and the question of space research was discussed with particular reference to the national benefits that could be expected to accrue from it. The Government's decision to discontinue *Blue Streak* as a military weapon has kept public, as well as scientific, interest in Britain focused on the subject, but in the meantime the announcement that the nuclear power programme is to be retarded has emphasized the comparative limitations of Britain's scientific and technological resources, and the critical character of decisions regarding the allocation of those resources as between one field and another.

There is, in fact, reason for believing that the proposals for space research are now much more realistic, and less likely to distort the general balance of effort in scientific and technological research. Lord Hailsham should be assured of strong and authoritative support in resisting any unrealistic proposals, and the Parliamentary debates and discussions on space research are, in fact, appropriately considered against the background revealed in the White Paper on the nuclear power programme published in June*. It might be noted that the retardation therein outlined was not foreshadowed in the usual White Paper on Capital Investment in the Coal, Electricity and Gas Industries† published two months earlier.

This earlier White Paper put the estimated capital expenditure by the electricity supply industry in England and Wales during 1958–60 at £308·2 million, of which £120·5 million was for conventional and £58·0 million for nuclear stations, compared with £275·4 million, £107·5 million and £46·0 million, respectively, approved for 1960–61; in addition, £6·4 million was spent on nuclear fuel in 1959–60 and £9·6 million is expected to be spent in 1960–61. Most of the expenditure on nuclear power stations in 1959–60 represented progress payments on main constructional works at the first four stations in the programme, and the White Paper notes that payments still to be made for those stations are likely to fall due earlier than had been estimated previously: increased expenditure under these contracts in 1960–61 will be offset by reductions in later years.

The White Paper on the nuclear power programme states that five nuclear power stations are being built and two more have been approved under the programme; the earlier stations will come into operation in 1961 and all seven should be in operation by 1966, with a total output capacity of about 3,000 megawatts. To reach the capacity of 5,000–6,000 MW. by the end of 1966, adopted in 1957 as the basis of the revised programme, exceptionally large orders for nuclear capacity would have to be placed during the next two years for commissioning in 1965 and 1966, and in the meantime the need on the grounds of fuel supply for a sharp and immediate acceleration in the rate of ordering capacity has passed. Accordingly, in consultation with the Atomic Energy Authority, the English and Scottish Electricity Authorities have re-examined the programme with the Government, in the light also of the latest estimates of nuclear and conventional costs and the future availability of primary fuels.

Although the cost of electricity from the first nuclear power stations to be commissioned next year will be rather higher than earlier estimates, the costs of later stations are following closely the downward trend foreseen in 1957, and while, for stations designed to-day, conventional power costs are about 25 per cent less than nuclear costs in the United Kingdom, the Government is advised that, in spite of the unexpected fall in the costs of conventional power from new stations, nuclear generation for base-load purposes is likely to become cheaper than conventional generation by about 1970. While there is a present world surplus of coal and oil, in the long run we shall need increasing supplies of nuclear power, and to secure this we must continue to build nuclear stations on an adequate scale.

The White Paper records the Government's decision to continue for the time being to place orders for nuclear stations at the rate of roughly one every year; and as the capacity of individual stations is likely to increase, this should provide about 5,000 MW. of capacity in 1968. Compared with the 1957 programme and allowing for more conventional stations, this will reduce by some £90 million the cost of power stations to be commissioned during the next seven years and there will be some loss to the Atomic Energy Authority. At any time there should be five or six stations in various stages of development, and it is claimed that this proposed rate of ordering should maintain fully the rate of development of nuclear technology in Britain and sustain a nuclear plant industry capable of competing for overseas business and of expanding to meet the higher level of the future needs of Britain itself.

The Minister of Power was closely questioned about the revised programme in the House of Commons on June 27; but he added nothing sub-

* Ministry of Power. The Nuclear Power Programme. Pp. 4. (Cmnd. 1083.) (London: H.M. Stationery Office, 1960.) 4*d*. net.

† Ministry of Power. Capital Investment in the Coal, Electricity and Gas Industries. Pp. 4. (Cmnd. 993.) (London: H.M. Stationery Office, 1960.) 6*d*. net.

stantial to what was contained in the White Paper, apart from stating that for calculating depreciation the life of nuclear power stations was taken as twenty years, though it might be longer, and when they reached the end of their useful lives they would be dismantled, except the reactors, which would be sealed up, and new stations might be built on the same site. On July 28, replying for the Minister for Science, Sir David Eccles said that the slowing down of the nuclear power programme would result in the Authority carrying large stocks of uranium, and it was estimated that the annual interest on the capital locked up in the additional stocks might amount to several million pounds: present estimates suggest that the Authority's current and prospective supplies of uranium would last about ten years. Apart from this, it seems sensible to defer part of the programme rather than run the risk of erecting costly and uneconomic power stations, though there must be some question whether the retarding of construction may hinder the development of more efficient types of reactor.

Sir Christopher Hinton scarcely seems to support this view. Discussing, in one of the Royal Society tercentenary lectures (see p. 1064 of this issue), the technical problems which must be solved to reduce the cost of nuclear power to an economically competitive level, Sir Christopher noted that at present the cost of electricity produced by nuclear power plants is 25 per cent higher than that produced by conventional coal- or oil-fired power plants, but that it is expected to drop below that of conventional power before 1970. He then suggested that it would be interesting to speculate on the cost of conventional power generation if it attracted as much research and development as its nuclear rival.

Here, of course, Sir Christopher touched on the essential difficulty that confronts anyone who carries the responsibility for allocating Britain's precious resources of scientific and technological man-power; and Mr. Aubrey Jones, the former Minister of Supply, has even implied that this is the essential reason for establishing a Ministry for Science. As he sees it, the main task of the Minister for Science should be to find a substitute for the technological role which armaments have hitherto played in a free society, with all that that implies in the allocation of resources, the stimulation of research and the fashioning of appropriate relations between industry and government. Mr. Aubrey Jones maintains further that the Minister must operate primarily on the side of demand, that he must seek ideas from industry, and avoid the dispersal of resources, concentrating them on a few major problems, and in particular he urged that the Department of Scientific and Industrial Research and the National Research Development Corporation should be brought into a closer relation and under the same authority—that of the Minister for Science.

The importance of a reasonable balance in the distribution of the resources of Britain is enhanced rather than otherwise by the interaction of different technologies which may be involved in such a field as that of nuclear power, to which Sir Christopher Hinton also alluded in the lecture already noted. Sir Christopher had emphasized that the heat-cycle temperatures in nuclear power plants are lower than the steam temperatures in conventional plants because of the combined effect of the inherent design of a nuclear reactor and the difficulty of finding materials which can stand up to irradiation. If comparable temperatures could be reached in a nuclear plant, Sir Christopher said that nuclear power would already be cheaper than conventional power. Here lie the major problems facing nuclear scientists and engineers at present, and little further advance can be expected, he said, until a new canning material is used for the fuel elements.

The annual reports of the Atomic Energy Authority have frequently indicated the benefits which other technologies have drawn from Britain's programme in nuclear energy, though those benefits are of themselves no justification for disproportionate expenditure of energy in any one field, and they are reasons for some information being published as to the expenditure on research and development by the Authority rather than otherwise. The essential lesson is the imperative need for effective co-ordination, in research and development generally as in fuel and power policy; and if either the Minister for Science or the Minister of Power lacks the authority or resources to formulate and execute such policies, he should not hesitate to approach Parliament for the necessary powers. That undoubtedly is a priority if Britain is to embark in space research on any considerable scale, and in the debate on July 29 Vice-Admiral J. H. Hallett very rightly stressed the need to re-examine the methods by which development contracts of the magnitude required in such programmes are co-ordinated and financed.

Although there are obviously still large problems of administration in research and development which demand some fresh thinking by the Minister for Science, it is no less important that we should be clear before embarking on any large programme of space research as to exactly what benefits the country may derive from such an effort. It is one thing to support projects such as those for which the Department of Scientific and Industrial Research announced last July the allocation of £184,540 to sixteen research groups in British universities for the development of instruments in rockets and satellites; it is quite another to contemplate a programme of space research demanding financial support on a scale comparable with that given to the rest of science. As Prof. Fred Hoyle has emphasized, space research is only a fragment of astronomy, and astronomy itself is only a fragment of science.

In opening the debate on July 29, Mr. G. de Freitas put national prestige as the chief argument for space research and development; but it is difficult to take this argument too seriously. Prof. Hoyle has also questioned whether we are likely to lose any able young scientists even if we do not embark on a space research programme. The really

important question is that discussed before the Parliamentary and Scientific Committee and, directly connected with the expected benefits from such a programme, namely, what is a reasonable level of effort in this field. On the scientific side, Sir Edward Bullard referred to the importance of a better knowledge of the high atmosphere for the transmission of radio-waves, to the new opportunities space research offers for investigation of the charged particles in space and for astronomical observations outside the atmosphere. The present programme, he said, is costing about £100,000–£150,000 a year, and he thought this might rise to about £200,000, which is the same order of magnitude as the Department of Scientific and Industrial Research's grant to universities outside nuclear science.

Prof. W. R. Hawthorne, however, urged a programme involving expenditure of £100 to £200 million over the next ten years on launching space satellites and probes, and justified his claim on the ground of advances anticipated in control devices, communications and power, as well as in structures and mechanical engineering. He thought, for example, that the impetus given by the jet engine to research and development in combustion was likely to be repeated as engineers tackled the problems of rocket combustion, and similarly in connexion with the transmitters and receivers designed for space research to detect weak signals in a background of noise would be invaluable to industry in the next decade. Beyond this, however, Prof. Hawthorne argued that failure to support a serious space project would reduce the number of innovations we develop, innovations which might be of material advantage to industry as a whole, and it would also reduce the resources of skill and experience on which our designers could draw. Innovation, he insisted, is a product of imagination, skill and chance, and without entering on any discussion of the relation between discovery and innovation, he strongly urged the importance of an environment which fosters innovation, such as a space project should provide, in the education of the engineer.

Sir Robert Cockburn said that, of possible applications of satellites, only their use for long-range communications, in reconnaissance and in navigation could yet be considered in detail, and Dr. Denis Taylor stressed more particularly the stimulus space research could bring to instrumentation and to continental telephone and radio communication. In the discussion, Mr. A. Albu questioned whether engineering and scientific achievements could not be maintained more cheaply by spending money in some of the industries. Prof. Hawthorne admitted that it is difficult to explain the working of the intellectual stimulus and, as he also said, the Department of Scientific and Industrial Research had long been seeking to introduce science into British industry, but with only partial success. He agreed with Lord Halsbury as to the need for understanding why industrial design teams and others behave as they do, and the discussion certainly focused attention on the critical importance to Britain of such understanding for the proper deployment of our limited scientific resources.

Something of this discussion was reflected in the debate in the House of Commons on July 29. Mr. de Freitas, asserting that for speech, and later for television, satellites offered a far greater capacity and economy than ordinary terrestrial radio or cables, quoted opinion from the telecommunications industry that while for the first three years a telephone call to Australia might cost £1 a min., within four years a profit would be made at 10*s*. a min., and within twenty years anywhere in the world could be reached at 6*d*. a min. and be highly profitable. It is estimated that this could be achieved for an outlay of £6 million in the first year and a total of £80 million over forty years, and the system should have an income of £3·7 million in the first year, rising to more than £50 million in twenty years.

Mr. de Freitas also referred to the use of these satellites for navigation and weather forecasting; but while, in replying on the debate, the Parliamentary Secretary to the Ministry of Aviation, Mr. A. G. E. Rippon, agreed that great scientific, technological and commercial benefits might be expected to result from space research, he pointed out that scientists themselves are divided on the question, and he again stressed the importance of considering the possibilities of international co-operation in this field. The debate had concentrated on the question of the development of *Blue Streak* as a satellite launcher, but on this Mr. Rippon had nothing to add to what the Minister of Aviation, Mr. Duncan Sandys, had told the House on June 20. Mr. Sandys said then that he was keenly aware of the potentialities of a British space research programme, but that he was not yet in a position to announce any decision. He also said that the French and German Governments appeared to be considerably interested in the idea of co-operation, but that before taking any decision the Government would consult the Australian Government.

Mr. de Freitas did not repeat what he had said in replying on the debate on February 22 about the British contribution to various space research programmes. Since the decision to abandon *Blue Streak* as a military weapon was announced, work had continued on those parts of the project which are necessary to its adaptation as a space satellite launcher and there was no evidence to show that these important design teams were splitting up, though he appreciated that excessive delay in reaching a decision could have adverse effects. Meanwhile, work on the technical problems associated with a future space programme had confirmed that a launcher could be developed from our abandoned military project capable of putting into orbit an array of satellites, and the design studies indicated that at least three types of satellite could be launched.

Although Mr. Rippon did not go into details of the scientific programme which could thus be carried out, his references to telecommunications, meteorology and to the stimulus of new technology and innovation

suggested that the Government has already been considerably impressed by what was said before the Parliamentary and Scientific Committee, the memorandum from the British Interplanetary Society and other representations. Equally it would appear that the Government is concerned to maintain the balance of the research effort of Britain and avoid the distortion which Prof. Hoyle and others fear. Some scientists like Sir William Slater and Dame Kathleen Lonsdale fear that space research will divert skilled man-power from more important fields of research; but while Sir Frederick Brundrett suggests that a programme of space research should normally run with a military programme for the development of liquid-fuelled rockets and thus, like Prof. Hoyle, appears to question whether the successful development of a satellite relay system really lies within the range of a *Black Knight–Blue Streak* programme, Prof. Hoyle seems to be alone in doubting whether sufficient sound ideas for space research have yet been advanced to prevent the decline in standards which tends to result if too much money chases too few ideas.

There seems little reason to doubt that the Advisory Council on Scientific Policy took the right line in its annual report for 1958–59, from which Mr. Rippon quoted in the debate on February 22. British science and technology have contributed, and will continue to contribute, valuable results in space research, but these contributions should be made in specific directions appropriate to our special skills and they should be part of an internationally based approach. There does not indeed appear to be any reason on financial grounds or those of scientific and technical man-power why Britain should not afford such a programme; but a sound decision will be reached much more readily when the results of the design studies recommended by the Advisory Council are available.

Meanwhile, the importance of a close assessment of the distribution of Britain's effort in research and development, including that of the universities as well as of Government and industry, is obvious, and this should be receiving the urgent attention of the Minister for Science. Moreover, it should not be forgotten that while Mr. Rippon rightly stressed the need to consider carefully all possibilities of international co-operation in space research, a report last March by Mr. D. Wilgress on co-operation in the field of scientific and technical research to the Organization for European Economic Co-operation strongly urged the need for more co-operation, particularly in fundamental research. Still more recently, industrial leaders like Viscount Chandos and Dr. Solvay have urged the need for more co-operation in fundamental research within particular industries, again on the ground of avoiding waste of limited resources, and especially of trained man-power. The Government is right in refusing to be rushed into any hasty or premature decision as to entering or not on a programme of space research; but it is for the Minister for Science to make sure that all the relevant factors are taken into account, including the interaction of different technologies on one another and the functioning of innovation and invention. Not all these factors can, it is true, be estimated with any accuracy; and there is sound reason for putting some further studies in hand. If the results will not be available in time to guide the decision regarding space research, they should assist similar decisions which are bound to recur from time to time in an age of advancing technology.

SEMICONDUCTORS AND TRANSISTORS

Les Semiconducteurs

Par Prof. P. Aigrain et F. Englert. (Monographies Dunod.) Pp. x+203. (Paris: Dunod, 1958.) 980 francs.

Les Semiconducteurs Électroniques

Introduction à la Physique des Redresseurs et des Transistors. Par Dr. E. Spenke. Traduit par L. Godefroy. Pp. xx+349. (Paris: Dunod, 1959.) 5,600 francs.

The Properties, Physics, and Design of Semiconductor Devices

By John N. Shive. (The Bell Telephone Laboratories Series.) Pp. xxi+487. (Princeton, N.J.: D. Van Nostrand Company, Inc.; London: D. Van Nostrand Company, Ltd., 1959.) 73*s*.

Transistors

By A. C. Gillie. Pp. xvi+262. (London: Prentice-Hall International, Inc., 1959.) 42*s*.

The Junction Transistor and Its Applications

Edited by E. Wolfendale. Pp. viii+394. (London: Heywood and Co., Ltd., 1958.) 84*s*. net.

THE subject of semiconductors was understandably not popular with authors of books during the period when the two semiconductors in common use, copper oxide and selenium, and rectifying contacts made to them, were proving such severe tests of the theories of the solid state then being developed. Industry found it necessary to use empirical methods to improve these materials for use in rectifiers, thereby, as it happened, tending to increase the difficulty of closing the gap between theory and practice.

The whole outlook of the subject was ultimately changed, not by the resolution of the difficulties which made the subject so obscure, but by rapid advances following comparable observations of materials more amenable to scientific investigation. Germanium in particular proved to be a semiconductor well suited to study by physicists; the discovery of transistor action and its explanation in terms of minority carriers acted as a great new stimulus, and the refinements made to the methods of preparing germanium, and later silicon, with very small, but controlled, amounts of desirable impurities quickly increased confidence in quantitative measurements. New electrical properties of semiconductors were discovered and fitted into the expanded theory, and its adequate explanation of the behaviour of *p-n* junctions was one of its greatest successes. To-day therefore, despite some difficulties which the subject has run into in its newer fields and in some details, the

basis of the subject is well established and the problems facing authors of books on the subject are an over-abundance of original and review papers and the rapidity of advance. In addition, the readers have changed; few continue to regard the subject as a test of the powers of quantum mechanics, for it has had important reactions on the basic theories and is big enough to demand specialized treatment. Most readers will be content if the specialized treatment is only sufficiently rigorous to contain the more important basic physical effects, and will expect a compact picture of the positive achievements and applications of the subject which has spread into several branches of science.

Prof. Aigrain and his co-author make little concession to these readers in so far as they assume that a study of quantum mechanics will already have been made—even if many details have been forgotten—and that frequent recourse to fundamentals is essential. They begin with a highly condensed account of the role of electrons in solids, largely in mathematical terms and divorced from physical quantities directly observable, into which they then fit a few practical findings. The bare outlines of the properties of junctions and transistors follow, expressions still being quoted rather than deduced, and the book ends on a lower intellectual note, with summaries of the preparation of transistor-quality germanium and silicon and of some photoelectric and thermoelectric applications. The merits of this short book as a summary of the formal theory for those readers already well acquainted with the subject are likely to be its greatest demerits for others.

The second edition of Spenke's book was translated into English last year by staff of the Radio Corporation of America, who made some useful additions; the French translation, which seems a little less free by comparison, includes the addition describing junction capacitance. The book is in two overlapping parts. The first four chapters form one part and take us from band theory to the physical mechanisms of transistors; mathematics and wave-mechanical ideas take second place to descriptive language, but the author avoids over-simplification. The second part is intended for the physicist who requires a more comprehensive analysis of the physical processes responsible for the properties of semiconductors. It reveals the more successful work of the period 1930–40, made despite the difficulty of experimental confirmation, though it may over-emphasize some at the expense of more recent findings.

Shive, too, though writing for readers with little prior knowledge, divides his book into two distinct parts. The first, once again, is very descriptive, both of semiconductors and of the chief devices made from them—thermistors, point-contact diodes, rectifiers using copper oxide and selenium, photocells and junction transistors. A scientist in a non-physical field could benefit equally with any newcomer. The second part begins by inquiring more deeply into the physics of semiconductors, largely in terms of particle models, with occasional reference to wave and quantum mechanics; some over-simplifications may have crept in, but the chief points are well put. The key points of junction theory are presented without frills, and the book concludes with chapters on thermoelectricity, the Hall effect and the processes used to make junctions. The whole is worth study by those who teach the subject as well as by those seeking a broad understanding which is, however, more than superficial.

Despite the fair number of books on transistors now available, it is still difficult to say how best the subject can be presented, either for beginners or for experienced designers of devices and circuits. If reasons are to be given for the electrical properties, some recourse to physics is necessary; but if they are not, a statement of the properties and their translation into analytic form can prove an adequate starting point for a book on applications. Gillie's attempt, aimed at a non-analytic introduction to the device and its elementary circuits, is not badly planned, but must be very nearly completely discounted because of the numerous errors and misleading statements early on. Thus he talks of the velocity of current, confuses resistance and resistivity, asserts, with the emphasis of italics, that pure germanium is an insulator, seems to imply that acceptors increase the conductivity of a semiconductor, because the electrons from the valence band filling the acceptor-levels then require less energy to be excited to the conduction band and states that hole-electron pairs can be more easily created in *n*-type material. The two chapters on the junction transistor can be recommended to the newcomer without serious reservation, provided he has other sources to refer to at the same time.

On the other hand, Wolfendale and the contributors to his book have produced something worth the serious attention of electronic engineers. The opening chapter, of some length, on transistor physics is specially noteworthy, for, from a simple beginning, it develops analytically all the main electrical properties of the uniform-base transistor; an extension to graded-base units would be valuable in any second edition. Several of the later chapters are of the standard expected in a good designers' hand-book, and all have some merit. Continuity is sometimes a little lacking, and some parts are treated in much more detail than others; but there are no inconsistencies and few misleading statements. The book was written before the idea was advanced that the charges stored in the base and in depletion layers furnished a basis for predicting the behaviour of transistors as switching elements; but it does illustrate the difficulties of finding a single representation for a transistor adequate for all applications.

J. R. Tillman

COMMUNICATIONS AND ELECTRONICS DICTIONARIES

Elsevier's Telecommunication Dictionary in Six Languages

English/American—French—Spanish—Italian—German—Dutch. Compiled and arranged on an English Alphabetical Base by A. Visser. Pp. viii+1011. (Princeton, N.J.: D. Van Nostrand Company, Inc.; London: D. Van Nostrand Company, Ltd., 1960.) 147*s*.

Swedish Supplement to Elsevier's Dictionary of Electronics and Waveguides

By W. E. Clason. Pp. iv+43. (Amsterdam: Elsevier Publishing Company; London: D. Van Nostrand Company, Ltd., 1960.) 20*s*.

THE first volume is a very welcome addition to the series of multilingual dictionaries published by the Elsevier organization. Its compilation is more than justified by the enormous progress that has taken place in the field of communications, both line and radio, in the past one or two decades. This

volume has been compiled by Mr. A. Visser, who retired a few years ago from the position of librarian and chief of the documentation section of the Netherlands Postal and Telecommunication Services. The basis of the book is the listing of all terms used in the telecommunication world arranged in alphabetical order in the English language. Below each term is given the equivalent word or phrase in French, Spanish, Italian, Dutch and German in that order. In many cases it has been necessary to give alternative words or phrases in interpretation of the basic English term or phrase. No definitions of the terms are given, but, in a large proportion of cases, the terms are sufficiently self-explanatory for the technical reader.

Following the basic section, alphabetical lists are given in each of the other five languages, each word being indexed as a reference to the basic table, so that the user can find the corresponding term in English, and all the equivalents in the other languages.

As with former volumes in this series, the production of the book is excellent. In spite of its size—more than one thousand pages—it is convenient to use, with the familiar semi-flexible binding, and a thumb-index to the different languages. All engineers and scientists engaged in the field of telecommunications will find this a most useful work of reference and aid to the reading of foreign literature.

A dictionary on similar lines to that referred to above but dealing with the field of electronics and waveguides was published by the same company in 1957 (see *Nature*, **181**, 801; 1958). To the language section of that volume has now been added a Swedish supplement. This is arranged in two parts: the first being an alphabetical list of terms in this language; while the second comprises a re-arrangement of the same terms in the numerical order corresponding to the numbered basic English section of the main dictionary. The publication of this supplement thus extends the former volume to be a complete work of reference in seven languages to all terms in use in the technique of electronics and waveguides.

R. L. Smith-Rose

PROBABILITY AND PHYSICS

Probability and Related Topics in Physical Sciences
By Mark Kac. With special lectures by G. E. Uhlenbeck, A. R. Hibbs and Balth. van der Pol. (Lectures in Applied Mathematics, Vol. 1.) Pp. xiii+266. (New York: Interscience Publishers, Inc.; London: Interscience Publishers, Ltd., 1959.) 43*s*.

THIS book, which is based on a course of lectures given in 1957, makes no claims to be a textbook; but it contains a wealth of material underlining the established place of probability technique in modern physics. Prof. Kac's enviable skill in analysis is somewhat naturally displayed to the full in many of the problems discussed, so that, while the mathematics always remain his servant, his book may in consequence appeal rather more to mathematicians than to physicists.

There are four chapters and four appendixes. Chapter 1 explains the nature of probabilistic reasoning, and includes discussion of the Maxwell velocity distribution in the theory of ideal gases and of the number of real roots in polynomial equations with random coefficients. Chapter 2 deals with "Some Tools and Techniques of Probability Theory", illustrated mainly by reference to various random walk problems. The longest chapter (3) is on "Probability in Classical Statistical Mechanics", and the first appendix by G. E. Uhlenbeck on 'the Boltzmann equation' should be read together with this chapter. Uhlenbeck's appendix gives a very clear survey of the various models, microscopic and macroscopic, mechanical (deterministic) and stochastic, that exist and the relations between them. In Chapter 3 itself, the fundamental problems and paradoxes of statistical mechanics are considered by reference to the Ehrenfest urn example, by the use of the so-called 'master equation' which represents a stochastic simplification of the exact Boltzmann equation, and by a modern account of Smoluchowski's brilliant theory of fluctuations.

The final chapter (4) is on "Integration in Function Spaces and Some Applications", and discusses the recent technique of path integrals introduced into quantum mechanics by Feynman and having analogues in the theory of stochastic processes. There is a relevant appendix (2) on quantum mechanics by A. R. Hibbs, recalling some of the special peculiarities of probability in this domain. The final appendixes (3 and 4) by B. van der Pol, on "Smoothing and Unsmoothing", and "The Finite Difference Analogy of the Periodic Wave-equation" and the "Potential Equation" respectively, are not directly related to the rest of the volume, which ends with some interesting historical notes and a bibliography.

One important topic omitted from this book is information theory; this might be explained by Prof. Kac's concentration on problems closely connected with his own researches. It might also be argued that this theory is more related to communication engineering than to physics: but more fundamentally its bearing on the concept of entropy and on theories of measurement has yet to be fully clarified. On the subject-matter of Chapter 4, the mathematical connexion between the Feynman integral and analogous integrals in stochastic process theory is stated clearly enough, but on a deeper physical level the differences seem puzzling and remain rather a challenge. I was also somewhat surprised not to find a more explicit discussion of the important class of probability problems associated with such work as Onsager's on the two-dimensional Ising model, to which a very fleeting allusion is made in the bibliography (p. 261). However, even this last comment can scarcely be a criticism of the book under review, when it is recalled that the author's intention was to indicate the scope and value of probability theory, and part, but by no means all, of its rapidly increasing range in physics.

M. S. Bartlett

ADVANCES IN GEOPHYSICS

Advances in Geophysics
Edited by H. E. Landsberg and J. Van Mieghem. Vol. 4: Pp. x+456. 12 dollars; 86*s*. Vol. 5: Pp. x+325. 10 dollars; 80*s*. (New York: Academic Press, Inc.; London: Academic Press, Inc. (London), Ltd., 1958.)

IN these volumes, as in past issues, geophysics is interpreted in the widest sense with perhaps a greater emphasis on pure geophysics than prospecting geophysics. If it is the editorial policy that the subjects selected for review reflect the state of research among the Earth sciences, it would appear that

meteorology and upper atmosphere physics lead the field, for almost half the articles in the volumes under review concern these subjects. The International Geophysical Year stimulated research in all branches of geophysics as Gerson's article "Polar Years to I.G.Y." (Volume 5) illustrates, and it is to be hoped that future issues of "Advances in Geophysics" will take account of this activity, particularly in the fields of geomagnetism and seismology.

In reviewing the organization and achievements of the First Polar Year, Second Polar Year and the International Geophysical Year, Gerson remarks on the accumulation of "mountains of undigested data". The institution of world data centres by the organizers of the International Geophysical Year to co-ordinate and standardize the accumulated data makes it all the more imperative that geophysicists should be trained in computer programming methods in order to assimilate this data. Any student in this field is well advised to read Holloway's review on "Smoothing and Filtering of Time Series and Space Fields" (Volume 4).

Hirvonen, in "The Size and Shape of the Earth" (Volume 5), describes recent advances in geodetic surveying and also discusses the application of Stokes's formula to determining the geoid. Those minute oscillations of the Earth's crust due to Earth tides are reviewed by Melchior in "Earth Tides" (Volume 4). The remarkable sensitivity of the horizontal pendulums, extensometers and gravity meters (which the author describes) is exemplified in the attempt during the International Geophysical Year to detect the change in Love's numbers with tidal periods attributed to motions in the fluid core. While Earth tides can be dealt with largely by static theory, ocean tides demand a dynamic theory. The theoretical and empirical study of tides in uniform and actual oceans is reviewed in Volume 5 by Doodson.

On microseisms, the late B. Gutenberg (Volume 5) emphasizes the difficulties inherent in a branch of seismology which deals with dispersed sources involving energy transfer from wind–water–Earth and propagation by surface and channel waves.

Junge, in "Atmospheric Chemistry" (Volume 4), reviews recent research on aerosols and trace gases. Among other trace gases the role of carbon dioxide in the heat budget of the Earth is discussed. In "The Physics of Cloud Modification", Volume 5, the entire history of cloud-seeding techniques is outlined by MacDonald together with a discussion on condensation and precipitation processes in clouds.

Further afield, Watanabe (Volume 5) gives an extensive account of ultra-violet absorption cross-sections and absorption processes in the ionized regions. Rocket and satellite studies have also contributed to the revolution now taking place in theories of magnetic storms which have a direct bearing on theories of the aurora. Chamberlain (Volume 4) reviews these theories, discussing at length the Chapman–Ferraro theory of storms since this remains the most rigorous treatment that takes account of auroræ.

Lapaz (Volume 4) provides the first extensive account of "The Effects of Meteorites upon the Earth" discussing not merely the composition, trajectories, etc., of meteorites but also the probability of their striking densely populated areas.

These two books maintain the high standards of previous issues and deserve a place on most geophysicists' bookshelves.

S. H. Hall

BIOLOGY OF POLLUTION

The Effects of Pollution on Living Material

Edited by W. B. Yapp. (Symposia of the Institute of Biology, No. 8.) Pp. xii+154. (London: The Institute of Biology, 1959.) 25*s*.

The Biology of Polluted Waters

By H. B. N. Hynes. Pp. xiv+202+2 plates. (Liverpool: Liverpool University Press, 1960.) 25*s*. net.

THE Church Army Press is perhaps partly to blame for the style of the Eighth Symposium of the Institute of Biology "The Effects of Pollution on Living Material". Although expensive the quality of production, paper and printing is poor and while this may have been specific to my copy the contents must be general. After two good introductory contributions the symposium lapses into a stage for mere repertory and is saved only by the last chapters on pollution, in its widest sense, by radioactive materials. Although at present mostly fall-out, some contribution to radioactive pollution is made by nuclear power stations and general radioactive waste disposal from hospitals and industry for which there is still no national scheme. With radioactive pollution at its present level, such effects as an eventual increase of 5,300 in the number of blind persons in Great Britain may be expected. It seems, however, that, except for tritium and carbon-14, both soft beta emitters, cobalt-60 with a half-life of 5 years is the longest-lived nuclide in fall-out. Improvement would therefore be quite rapid if bomb testing was to stop.

While the chemist interested in water has for a long while been well equipped with books on pollution, biologists have hitherto had probably only one recent book, namely "Aspects of River Pollution" by Dr. L. Klein, to draw upon. That work is primarily a reference book, while "The Biology of Polluted Waters", by Dr. Hynes, in which frequent reference is made to Dr. Klein's book, provides for the first time an introductory text for any biologist sufficiently interested in pollution to be intrigued by the striking cover. In the preface and throughout the book Dr. Hynes emphasizes the essentially biological nature of pollution and the incongruity of the older chemical approach. Mr. F. T. K. Pentelow too, who wrote the introduction, criticized some of the river boards for expecting the chemists on their staffs to understand and tackle alone problems so essentially biological.

Having experienced the difficulty of communication with chemists who are often unfamiliar with biological concepts, the author has provided a kind of picture vocabulary to help the non-biologist reader, but it is doubtful whether this simple device will in fact bridge the gap between the worlds of the chemist and the biologist.

To most people pollution has a definite connotation; but perfectly natural phenomena, such as the autumn fall of leaves or a sudden summer shower, may deplete the dissolved oxygen in a river enough to be catastrophic for the inhabitants. Similarly, pollution of lakes may merely hasten the natural hydrosere from oligotrophic to eutrophic condition. Where then is the border-line between natural and polluted water? Only complete understanding of the biology of a whole waterway can justly answer this question in any particular case, yet, as the author points out, still too little is known for this often to be possible. Perhaps the best basis for a general judg-

ment on the condition of a river is given by Turing cited by Hynes. "Fish are a very useful barometer of the real state of purity of a water. No river should be considered as in a satisfactory condition unless fish will live and thrive in it".

In short, the book sums up the work of the Water Pollution Research Laboratory, the Freshwater Biological Association and authorities in Europe and the United States, in a comprehensive and above all eminently readable way. G. C. WARE

NORTH AFRICAN PREHISTORY

The Stone Age in Northern Africa

By C. B. M. McBurney. (Pelican Book No. A342.) Pp. 288+24 plates. (Harmondsworth, Mddx.: Penguin Books, Ltd., 1960.) 6*s*.

DR. McBURNEY is among the half-dozen prehistorians who are really competent to write about the early prehistory of North Africa. Over a series of years he has visited much of the area and has himself made there important excavations. His book, therefore, can be confidently recommended to all students of the subject.

As a lecturer and teacher in the University of Cambridge who has travelled widely, he brings to bear on the problems of North Africa a wide knowledge of prehistory elsewhere, and seeks to fit his special area into the pattern of the Stone Age world. Thus he begins his book with 60 pages on "The Present Stage of Prehistoric Studies"—a chapter which will be appreciated both by his less- and more-instructed readers, and which presents the problem of North Africa in relation to the neighbouring areas of Europe, western Asia and Africa south of the Sahara. He then discusses the physical and climatic problems of his own region. Climatic changes in the past have profoundly affected the possibility of habitation during prehistoric times. Prior to the last pluvial period (Gamblian) the spine of the Sahara could be traversed from south to north, but afterwards such movements were, to say the least, difficult on account of the absolute desert conditions which set in.

Next come three chapters which perhaps are the meat of the book and which deal, in order, with "The Earliest times of Man in North Africa", "The Middle Palæolithic" and "The Blade Industries and the Spread of *Homo sapiens*". In the first of these it is splendid to be given, with proper recognition of its importance, an account of the work of Arambourg and his finds of early Acheulean human remains at Ternifine (Palikao). To English readers such an account has not hitherto been readily available. Villafranchian faunal assemblages used as date-giving fossils are discussed and there are comparative faunal tables and some, perhaps not enough, text figures of varying excellence of some of the implements found. In the Middle Palæolithic chapter the author has much excavated material to discuss and many problems, and can draw on the work of Miss Caton Thompson again and again. There is a charming account of his own finding of a hunter's encampment site near the Wadi Derna in Cyrenaica, with a list of the animals eaten there, and where the typology of the finds brings to mind the industrial tradition of the lower Levalloiso–Mousterian of Palestine. In the "Blade Industries" chapter his own excavations have again helped the writer. The problems are more than ever complicated as he admits, but as a working hypothesis he offers a series of dates starting at 15,000 B.C. with the appearance of the earliest Oranian in the Maghreb as a result of Gravettian influence or immigration from south-west Europe into a Levalloisean area until 5000 B.C., when the Upper Capsian seems to come to the end of its sway and Levantine influences are apparent. A final chapter on the Neolithic period, which gives a picture of a surprisingly uniform cattle-breeding (but sheepless and goatless) economy extending from the Atlantic to the Nile, includes a short account of less than 15 pages of the North African rock-shelter art and about the same number of pages of illustrations, principally, I fancy, taken from Frobenius. On this matter, of course, a great deal more could be written, but the survey will be found useful to students. It is in a connexion like this that one must regret that owing to the economic problems of to-day such a fundamental study as this book could not have appeared in a larger format. So much which the author has touched on could have been usefully expanded. Nevertheless we now have, together with the complementary volumes in the series by Desmond Clark and Sonia Cole, three authoritative works on the prehistory of the continent of Africa.

M. C. BURKITT

EXISTENTIAL PSYCHIATRY

The Divided Self

A Study of Sanity and Madness. By Dr. R. D. Laing. Pp. 240. (London: Tavistock Publications, 1960.) 25*s*. net.

THIS book will be of interest to those who are orientated towards philosophy, but others may find it difficult going. The author is obviously widely read in existential and other modern philosophical theories and has attempted to apply them to understanding psychiatry—particularly schizoid personalities and schizophrenia.

The main weakness of the book is that it does not develop a coherent system, but uses the existential ideas to explain some patients' symptoms without giving a satisfactory scheme which is applicable in other cases. In some instances he sets up 'Aunt Sallies' only to knock them over. For example, he complains that "the current technical vocabulary currently used splits up man verbally". By this presumably he means that one speaks of the ego, super-ego and id and so on. Yet this does not split up man verbally unless one regards an engineer who talks of the cylinder, piston, connecting rod and crank-shaft as splitting up an engine verbally. They are merely descriptive terms, and he still regards it as a whole engine.

The author puts forward a number of interesting mechanisms in schizophrenia, for example, engulfment, implosion, petrification, and depersonalization. He believes that the 'inner self' undergoes various changes in this disease and can be 'phantasicized' or 'volatilized'; it can become unreal, or impoverished, empty, dead, or split; it can be more and more charged with hatred, fear and envy.

The author complains that psychiatric theory has not changed since Kraepelin (although Freud changed a good deal), and perhaps he has laid the foundations of a system which he may be able to develop further in other books. CLIFFORD ALLEN

Safety in Mines Research Establishment Bibliography, 1960

Compiled by E. B. Smith. Second edition. Pp. viii+177. (Sheffield: Ministry of Power, Safety in Mines Research Establishment, 1960.) 17*s.* 6*d.*

THE organization known since 1950 as the Safety in Mines Research Establishment of the Ministry of Power has operated in one form or another since 1908. It has made noteworthy contributions to knowledge not only of the immediate problems of safety in mines connected with dusts, ventilation, inflammable gases, explosions, roof control, methods of working, lighting, health of the miner, electrical hazards, materials used in mining, and so forth, but also of fundamental scientific knowledge to a whole wide range of subjects which affect mining and mining conditions. These include physics of liquids and of fine particles, gas flow, ignition and combustion of gases and solids, flame propagation and explosions, metallurgy, coal constitution, palæobotany, medical science, etc.; this list is not exhaustive, but is a selection to show the breadth of interest of the Establishment as a whole. There are, in fact, more than 1,500 entries in this comprehensive bibliography (which supersedes the Safety in Mines Research Establishment Bibliography, 1921–52, and includes publications up to the end of 1959, as well as references to international conference papers translated and published by the Establishment).

The scope of the Establishment is wide because problems of safety in mines touch almost every science and technology. The bibliography, therefore, will be of interest to workers engaged in many fields of pure and applied science. It is well arranged and well presented for its price; but what a pity that it is stapled in such a way that the sharp ends of the staples can scratch—and in the case of one copy already have scratched—the surface of a polished table.

S. G. WARD

South African Animal Life

Results of the Lund University Expedition in 1950–1951, Vol. 6. Edited by Bertil Hanström, Per Brinck and Gustav Rudebeck. Pp. 553. (Stockholm: Almqvist and Wiksell, 1959.) 75 Sw. kr.

A CONTINUATION of what has now become a well-known series, this sixth volume follows the style of its predecessors. Like them, it is particularly pleasant to use because the various type-faces are well-chosen and attractive, and combine to make the text most readable. The crown octavo pages are bound in such a way that the volume stays open without trouble. A consistent editorial policy makes all papers present equivalent information: synonymy; systematic notes; descriptions of new genera and species; detailed and general distribution. The volume as a whole is rather lightly illustrated, though some papers have good figures.

This sixth volume includes accounts of the following groups of animals, as they were represented in the collections made by the Lund University Expedition during 1950–1951: Hirudinea (I. Sciacchitano); Diplopoda, Penicillata (B. Condé); Collembola (J. Paclt); Coleoptera, Scarabaeidae-Hopliini (H. Schein); Bostrychidae (J. M. Vrydagh); Erotylidae (H. Philipp); Endomychidae (H. F. Strohecker); Colydiidae (R. D. Pope); Monommidae (H. Freude); Cerambycidae (F. F. Tippmann); Chrysomelidae I (G. E. Bryant); Chrysomelidae II (J. Bechyné); Curculionidae, part (G. A. K. Marshall); Curculionidae-Brachycerinae (E. Haaf); Neuroptera, Planipennia II (B. Tjeder); Diptera, Culicidae (J. Muspratt); Ceratopogonidae (B. de Meillon); Mydaidae (M. Bequaert); Stratiomyiidae (E. Lindner); Phoridae (E. M. Beyer); Dorilaidae (Pipunculidae) (D. E. Hardy); Chloropidae (C. W. Sabrosky); Hippoboscidae (J. Bequaert); Streblidae (B. Jobling); Calliphoridae (F. Zumpt); Hymenoptera, Ichneumonidae (P. L. G. Benoit); Gasteruptionidae (J. J. Pasteels); Megalyridae (K. J. Heqvist); Sapygidae (P. L. G. Benoit); Pompylidae (G. Arnold); Amphibia (R. F. Inger).

There is a contents page, but this volume is not separately indexed.

H. OLDROYD

Les Observatoires Astronomiques et les Astronomes

Par Fernand Rigaux. Pp. ii+452. (Bruxelles: Observatoire Royal de Belgique, 1959.) n.p.

THIS is a new edition of a work which appeared originally in 1931 and has been very useful as a reference book. Many astronomers must have regretted frequently that the only supplement was made in 1936, so that the work was no longer of any use. It gives the names of the astronomers in all the principal observatories, and a brief description of the instruments to be found in them, and in addition it gives the addresses of retired observatory astronomers, university professors and lecturers interested in astronomy, and indeed of prominent amateur astronomers.

While the Royal Observatory of Belgium, and Fernand Rigaux in particular, are to be congratulated on the production of a new edition, it is impossible not to regret the fact that the information which now appears is four years out of date, at least so far as several British observatories are concerned that I have checked in detail. One might also suggest that a formidable book of 452 pages is not really necessary to convey the information. It is possible to criticize the lay-out, which seems to be very wasteful of space.

I would be heartily in favour of bringing out this reference book more frequently in a handier and cheaper form.

R. v. d. R. WOOLLEY

The Faith of a Physicist

By Dr. H. E. Huntley. Pp. 159+4 plates. (London: Geoffrey Bles, Ltd., 1960.) 16*s.* net.

IN a foreword to this book, Prof. C. A. Coulson commends it "as an honest attempt to help others to see the present status and future possibilities of science. In its simple and direct style it can hardly fail to instruct and to encourage its readers".

It is desirable that writers with a special knowledge of one branch of science should, on occasion, relate their scientific outlook to their attitude towards the Christian faith. This the author, lately professor of physics in the University College of Ghana, has done. In the first chapter, "The Status of Science", Prof. Huntley maintains that science "is not only more than technology; it is more also than a social force of unprecedented power. *Science is a revelation and its study is a religious activity*". Successive chapters expand this theme in relation to such subjects as education, beauty as revealed in Nature and the stature of man.

A feature of the book is the number of literary quotations which the author uses to illustrate his argument.

H. D. ANTHONY

EVOLUTION OF NUCLEAR POWER PLANT DESIGN*

By Sir CHRISTOPHER HINTON, K.B.E., F.R.S.

MOST applied research is expensive, and applied research and development on atomic energy is so expensive that expenditure should be justified either by the needs of defence or by the expectation of a satisfactory return in the industrial field. The foundations of the atomic energy industry were paid for with defence funds; the research, development and engineering of the fuel-element manufacturing plant at Springfields, the diffusion enrichment plant at Capenhurst and the Windscale reactors and chemical separation plant were done to produce plutonium and uranium-235 for defence. Even the Calder Hall reactors were built primarily for the production of plutonium, and generated electric power as a by-product. The possibility of using this experience in the industrial field had been seen from the first, and progress into this field had been planned. But now that we have advanced into it, little of the further research and development which are necessary can reasonably be charged to a defence budget; they must be justified by immediate or prospective savings as compared with alternative industrial techniques which are available or are likely to be available.

When the British nuclear power programme was first launched in 1955, it was estimated that (in the first stages of development) the cost of nuclear and conventional power would be equal at about 0·6*d.* per unit of electricity. Since then there have been three important changes; because of rapid development in that field, the cost of conventional power has fallen by more than 10 per cent; for technical and commercial reasons the credit allowed for by-product plutonium (which it is hoped to use as fuel in reactors of advanced types) was drastically reduced; interest rates (which had been taken at 4 per cent) have risen, and this rise reacts against nuclear power with its high capital cost. The result of these changes is that nuclear power from the plants which are now being ordered will cost about 25 per cent more than from the best conventional plants built concurrently and operated under similar load conditions.

That a difference of this sort was likely was known at the time when the nuclear programme was expanded in 1957; the expansion was justified by the immediate anxiety about fuel supplies in Britain at that time, by the fact that forecasts then made of fuel available for electricity generation suggested that the ceiling would be reached by 1965, and by the fact that (because the nuclear power industry was new) important reductions in cost could be expected. Since then both the short- and the long-term positions in regard to coal supplies have changed; there is a present surplus of steam coal, not only in Britain but also in many overseas countries; the long-term forecast of supplies of coal for steam-raising suggests that (without a nuclear programme) supplies could meet demand until about 1970. In these changed circumstances the nuclear programme was revised in June 1960, but the reduced programme can only be justified if it gives promise that it will give cheaper power than can be obtained from conventional fuels at a reasonable date in the future. If it gives that promise, as indeed it does, a programme involving the construction of many successive power stations, each of which will be less economical than conventional stations built concurrently, is justified, because research, development and large-scale construction and industrial use must move forward hand in hand; research in such a field is not effective if it moves too far in advance of application.

The cost of power from every form of prime mover has fallen as, with the passage of time, it has been possible to achieve higher top temperatures in the heat-cycle used by that prime mover. When the first industrial reactors were built at Windscale, the heat of fission was wasted because it was not possible to recover it at a high enough temperature. In the Calder Hall reactors the heat was recovered at a temperature just high enough for use; but even in the industrial reactors which are being built to-day, the top temperature of about 380° C. which is being achieved in the steam-cycle is at a level which was common in conventional steam-power plant practice twenty-five years ago. Nuclear power can thus be made cheaper by achieving higher temperatures in the heat-cycle; types of reactor which do not give promise of these high temperatures are only of passing interest or of interest only in specialized fields of application.

But advances in technology bringing down the cost of power generation are still taking place in the conventional field, so that the point at which the cost of nuclear power breaks even with, and then falls below, the cost of conventional power is determined by the convergence of two falling curves of cost. Before we look at the prospects in the nuclear field, it is worth while to examine the trend in conventional power plants.

The downward trend in capital cost of steam-power plants extends back to the earliest days of the steam engine (Fig. 1). The scatter of points on which the curve is based is naturally wide because plants have (at each date) been built of different sizes and for different conditions, but the trend is clear. In this period the top temperature in the steam-cycle has risen from 100° C. to 570° C. or, in some present-day pioneering plants, even higher. It would be wrong to suggest that the continuing fall in capital cost is due only to continued ability to achieve higher top temperatures in the heat-cycle, but the advance to higher temperatures is the backbone of the development. The use of higher top temperatures was naturally accompanied by the use of higher steam pressures; these made the use of boilers and turbines of higher capacity both possible and desirable. The use of these sets of larger capacity (as in all prime movers) brought down the capital cost per unit of output to an extent which outweighed the higher cost of the special materials of construction used to withstand the higher temperatures. The use of higher

* Royal Society Tercentenary Lecture, delivered on July 20.

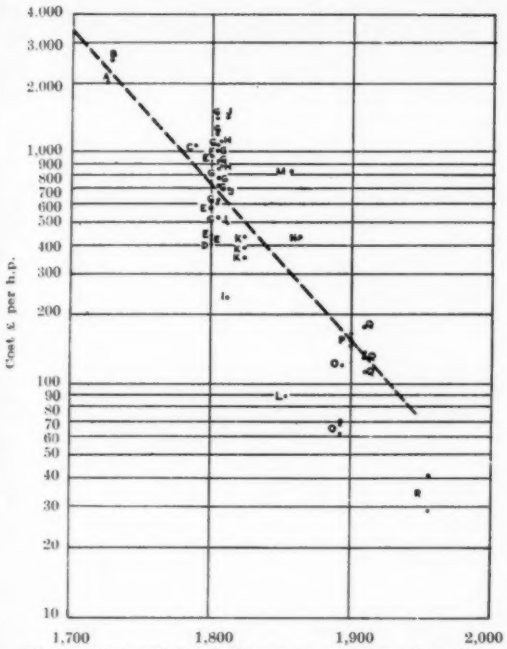

Fig. 1

temperatures and the practicability (provided by the use of higher pressures) of using re-heat, increased thermal efficiencies and combined with the reduced capital cost to reduce the cost of generation.

To project this trend into the future we have to take into consideration other factors in design (such as transport of components to site) and in operation, such as the size and stiffness of interconnexion of the British electricity grid system.

Before we can use the forecast of capital cost and efficiency prepared in this way to predict the future cost of conventional power, we must also forecast the cost of coal. It is interesting to find that this forecast of future coal costs, depending as it does on competition from oil and nuclear fuels, on social habits, economic conditions and on Government policy, is far more uncertain than the forecasts of capital cost and thermal efficiency either in the conventional or the nuclear fields, great as are the uncertainties in both of them.

When these predicted coal costs are applied to stations having the capital costs which are forecast, we find that the cost of conventional power in future years will be as shown in Fig. 2. It is with these costs that nuclear power must compete.

Atomic energy does no more than provide a third fuel (alternative to coal and oil) which can be used in steam-power plants generating electricity. If, with this fuel, we could achieve the same top temperatures in the heat-cycle that are achieved with conventional fuels, nuclear power could to-day be cheaper than conventional power. That we cannot do so is obviously not due to difficulties in the boilers or turbines; it is due entirely to problems within the reactor. In descending order of difficulty these problems are concerned with the fuel elements, the moderator, the control of reactivity and the materials of engineering construction.

The top temperature achieved in the heat-cycle in nuclear power plants of the type favoured in the United Kingdom is determined by the bulk outlet temperature of the coolant gas from the reactor, and this is determined by the temperature tolerable in the hottest fuel element. The upward trend of the achievable temperature is shown in Fig. 3. In the Windscale reactors—built to a tight time-schedule for the production of plutonium for defence purposes—it was the temperature limitation in the fuel elements that made power production impracticable. For ease of manufacture and for nuclear economy, the fuel elements were 17 in. diameter rods of cast uranium enclosed in aluminium cans; the use of magnesium as a canning material was rejected partly because an early and inaccurate determination made its neutron absorption cross-section appear unattractive, but ultimately because of risk of fire in the reactor. When arrangements for manufacture were well advanced, the danger arising from formation of UAl_2 by interaction between can and metal was realized and dealt with by oxidizing the surface of the uranium bar and coating it and the inside of the can with colloidal graphite. This solution was satisfactory only for the modest conditions of the Windscale reactor, where the maximum surface temperature of the can was 300° C. and where (because of considerations connected with weapon design) the maximum irradiation of the fuel elements was less than 500 MW. days/tonne. Even at these low irradiations, the intercrystalline movement (due to heat-cycling a material in which the coefficients of expansion are greatly different in different crystallographic direc-

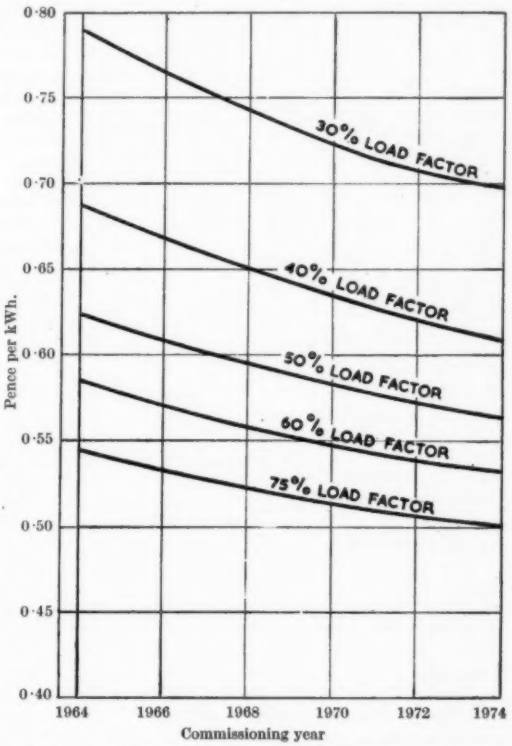

Fig. 2. Forecast of cost of electrical power from coal-fired stations at various load factors

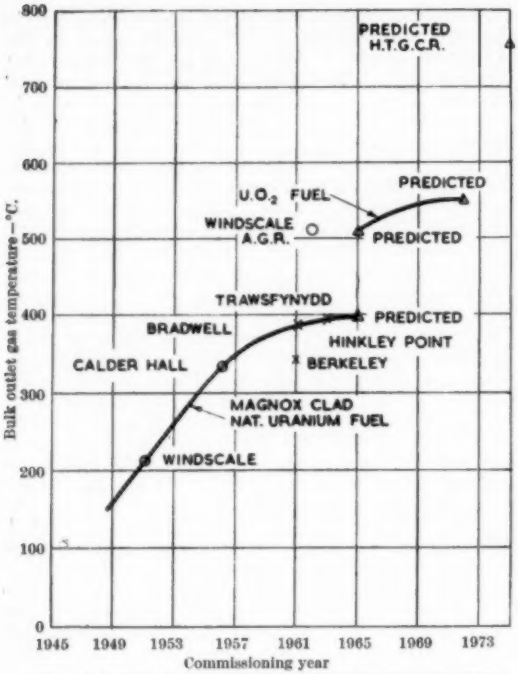

Fig. 3. The trend of outlet gas temperatures in British industrial reactors

tions and due to dimensional changes within single crystals caused by neutron irradiation) caused surface wrinkling which was liable to break down the barrier of colloidal graphite and permit metallic contact, formation of UAl_3 and can failure. Wrinkling was controlled by heat treatment to produce a fine random grain size; but the danger of the UAl_3 reaction, which increases with temperature, prevented advances while aluminium was used as a canning material.

It was the development of magnesium alloys containing small quantities of beryllium, calcium and aluminium to reduce the possibility of rapid oxidation and fire in the reactor which made the use of magnesium as a canning material practicable, and enabled us to reach outlet-gas temperatures which made power generation possible. But this magnesium alloy (magnox) has its disadvantages and limitations: at the operating temperatures in the cooler part of the reactor, it has a low elongation to fracture with low rates of deformation (a defect that can be minimized by careful design) and worse, it melts at about 640° C. Present reactor practice gives maximum surface temperatures of cans of 450° C. with possibilities of higher temperatures, so that little advance can be expected until change is made to another canning material.

Two alternatives are available to make the use of higher temperatures possible; stainless steel—cheap in itself but expensive overall because its high neutron cross-section makes enrichment of the fuel necessary—and beryllium, which gives economy of neutrons but it is an expensive metal.

The research by the Atomic Energy Authority on beryllium has been most ably done. When its development programme was started, little was known about the fabrication of beryllium; forming and joining techniques had to be found to give components of adequate strength and ductility. Techniques of consolidation and fabrication have been developed to the point where thin-walled tubes, rod, and forgings can be consistently produced to the close dimensional tolerances which are necessary. The mechanical properties of the fabricated metal are not the same in different directions (for example, the ductility of extruded metal is greatest in the direction of extrusion and is much smaller at right angles to this direction), and this has necessitated work to determine the metallurgical structure of the fabricated metal, with the view of optimizing the mechanical properties.

The high reactivity of the metal at elevated temperatures complicates the problem of joining, and it is necessary to use arc welding in argon or helium of high purity in order to achieve the desired results; as little as 0·05 per cent of oxygen in the welding atmosphere is sufficient to make the weld unsound. At high temperatures, beryllium is attacked by most metals and by carbon dioxide, and it is possible that this reaction may limit its operating temperature in reactors cooled with carbon dioxide to not much above 600° C. Energetic neutrons react with the nuclei of beryllium to form helium atoms within the crystal lattice, and these affect the mechanical properties of the metal and may limit its useful life in a reactor; an irradiation programme has been arranged to examine the problem and the first results are reasonably encouraging.

Further expansion in beryllium production will reduce the price, but it will always be expensive. Because of its high toxicity, great care is necessary in handling it; but experience shows that neither the scale nor the type of operation need be limited provided that the fabrication plant is properly designed. The problem of the poor ductility remains; but recent work suggests that the ductility is closely associated with impurities, and that this fault may be resolved by control of composition and by heat treatment.

Though the use of stainless steel or beryllium as a canning material opens the way to the use of higher temperatures, it means that in either case the cost per tonne of fuel elements will be far higher than with magnox. This increase must be offset by using higher ratings and by achieving higher burn-ups, both of which requirements force us away from the use of metallic uranium as a fuel.

In present practice the uranium centre temperature in the hottest fuel element is 590° C. Higher ratings necessarily mean higher temperature gradients, and when these are imposed on the higher temperatures of the surface of the cans that we must achieve, they bring conditions into the range where the phase change of the uranium will certainly cause trouble.

In reactors using metallic uranium fuel elements, we are hoping to achieve an average burn-up of 3,000 MW. days/tonne of fuel. It is improbable that figures much in excess of this will be achieved because (apart from distortion caused by crystalline movement due to irradiation and heat cycling) there is a volume increase due to the formation of fission products some of which are gases which can coalesce and cause swelling.

We thus find that to achieve the higher temperatures required, we are forced to use beryllium or stainless steel as a canning material; either course increases the cost of fuel elements. This must be compensated for by achieving higher ratings and higher burn-ups, and this can only be done by using uranium in ceramic form as our fuel.

Let us now consider the problems of the moderator. Graphite was used in the early stages of the U.K. project because we had no alternative. It has continued in use because it still seems to give the greatest economy in capital and operating costs; but its chemistry and physics under reactor conditions are still incompletely understood and it still presents a problem.

Reactor graphite does not oxidize quickly in carbon dioxide at temperatures below about 600–650° C. in the absence of radiation. In a pile, however, the carbon dioxide undergoes radiolysis with the production of active species which readily oxidize the graphite. This reaction causes a loss of graphite, with a consequent reduction of mechanical strength and moderating power; furthermore, carbon removed by oxidation may be deposited in the cooling circuit. The rate of reaction increases with the energy absorbed by the gas and thus with the gamma-ray flux and the gas pressure, and might, unless checked, become an embarrassment in advanced systems.

Studies of the reaction mechanism and methods of limiting the reaction-rate are being developed. One possible solution is to add to the coolant a gaseous inhibitor which will react preferentially with the active species. Carbon monoxide has proved to be effective, though it is possible that the benefit which has been observed is not caused by an inhibiting effect on the active species but by deposition of carbon produced by the radiolysis of carbon monoxide. A second possibility of reducing the attack depends on experimental evidence that most of the loss of weight is due to reactions on the internal surface of the graphite. It is probable that formation of active species occurs within the graphite pores (which constitute about 25 per cent of the volume of reactor graphite) so that the rate of reaction should be reduced by the sealing of these pores.

The physics problems of graphite result from the displacement of carbon atoms by fast neutrons having energy greater than the bond-energy in the crystal.

The first main effect is that the displaced atoms represent an accumulation of energy in the crystal; raising the temperature of the graphite partly anneals this damage, with liberation of the stored energy as heat. At low irradiation temperatures the energy stored in graphite can be considerable, and the Windscale reactors were periodically annealed in order to release this energy under controlled conditions. As the temperature of irradiation of graphite is raised, so the net damage to the graphite decreases, since under thermal activation a larger proportion of the displaced atoms return immediately to the vacant sites. The problem can be dealt with in practical reactor design by using moderator temperatures which, while sufficiently high to reduce the stored energy to tolerable levels, are well below the temperatures at which the chemical reaction between graphite and carbon dioxide becomes serious.

The second main effect is a change in the dimensions of the graphite blocks under irradiation. Displacement of carbon atoms causes the inter-planar spacing of the layers in the graphite crystal to increase and the layers themselves to contract slightly. These changes are integrated over the block (in which there is a preferred orientation of crystals) to give an increase in its transverse dimensions and a small shrinkage in the longitudinal direction. As with stored energy, the magnitude of this effect increases with the dose of radiation and decreases with rise of temperature. At temperatures of more than about 300° C., there is a second dimensional effect which, as yet, is not well understood and which gives rise to a contraction in both directions, possibly due to a closer packing of the crystallites. It is clear that there is still much research to be done on graphite under advanced reactor conditions.

Next in our descending order of difficulty as we advance in reactor technology were the problems of reactor stability and control, which become more acute when higher ratings and burn-ups are used. The basic reason for using gas-cooled instead of liquid-cooled reactors in 1946 was that they could not become instantaneously supercritical, and the large safety distances required by the original Hanford reactors were unnecessary. Operating experience showed that, with the low burn-ups used at Windscale, the reactors had a negative temperature coefficient and were, in fact, self-regulating. At higher burn-ups, however, the build-up of plutonium in the reactor reverses that part of the temperature coefficient which is associated with the graphite. This complicates the analysis, but the overall effect is that control must be by movement of the control rods, and care must be taken to see that departure from normality cannot be too rapid to be corrected with absolute certainty. The problem of xenon poisoning becomes more acute at higher ratings; it may cause oscillatory disturbances (which would be aggravated by the effects of build-up of plutonium), and it can also make it difficult to re-start the reactor after a shut-down. It is fortunate that the temperature coefficient of the fuel element remains negative and that it is strong enough to give an effective stabilizing influence in rapid transients.

Last and least in our order of difficulty were the problems of engineering construction, and these are mainly connected with the pressure system. The large pressure shells which are at present used in reaction construction demand thicknesses of plate so great as to minimize the opportunity for rolling and cross-rolling in fabrication, and there must be a danger of persistence of casting defects and coarse grain in the steel. Welding these thick plates is not easy and the problem of brittle fracture (which is increased by neutron irradiation) demands close attention in design, fabrication and operation. These problems are reduced by the use of higher fuel-element ratings because the dimensions of the pressure vessel for given heat-output are reduced. The use of higher bulk-gas outlet temperatures would give rise to other difficulties if the pressure shell were exposed to these temperatures, but designs can be evolved to avoid this.

It is this history and this present state of knowledge and development that has led the Atomic Energy Authority to the design of the advanced graphite reactor that is being built at Windscale as a prototype for the next logical step forward in technology. It is designed to achieve a bulk outlet gas-temperature of 510° C.; the gas flow is so arranged that the pressure shell is not exposed to this temperature but only to gas at a temperature of 320° C. which has passed through the heat exchangers. The design of the fuel elements is such that either beryllium or stainless steel can be used for canning, with uranium oxide fuel. The arrangement of the graphite moderator is conventional; the graphite loss due to corrosion during the life of the reactor is calculated to be tolerable, but more work is needed to check this point and to develop satisfactory conditions.

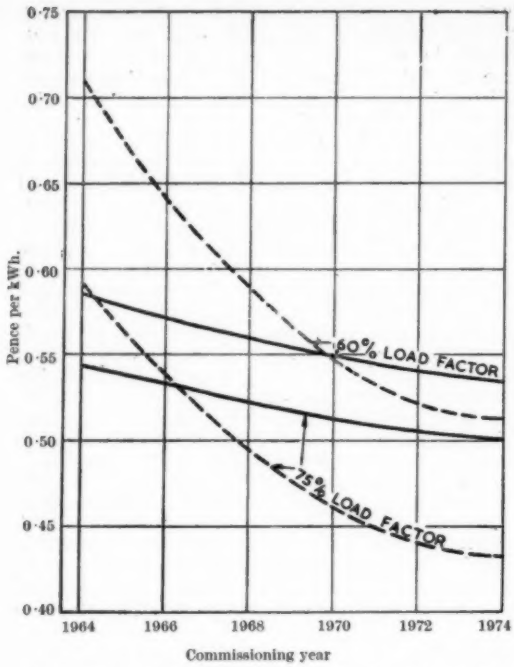

Fig. 4. Forecast of nuclear and conventional power costs in Great Britain. ---, Nuclear plant; ———, conventional coal-fired plant

It is estimated that the capital cost of the first industrial plant of the advanced graphite reactor type will be between £95 and £80 per kW. sent out, and that they will generate power at a cost of between 0·55*d.* and 0·50*d.* per unit or perhaps a little less at a load factor of 75 per cent; these cost brackets are naturally wide at a time when much development remains to be done.

The advanced graphite reactor represents the next logical step forward in British reactor practice; but, just as nuclear power finds strong competition from conventional power in establishing its new technology, so the new advanced graphite reactor must meet competition from the better established reactors of the Calder type in the early stages of its development. The advanced graphite reactor starts with the advantage of being able to achieve higher temperatures in its heat-cycle than are possible in magnox reactors, but in its race to supersede them it is competing with a technology which has advanced rapidly and is capable of further advance. Let us then look at the industrial progress of the magnox reactors with which the advanced graphite reactor competes.

The downward trend in cost of the nuclear power plants which are being built by the Central Electricity Generating Board in Britain can be closely estimated, and is shown in Table 1.

Table 1

Station	Capacity (MW. sent out)	Cost (£/kW. sent out)
Berkeley	275 (2 reactors)	160
Bradwell	300 ,,	159
Hinkley Point	500 ,,	133
Trawsfynydd	500 ,,	123
Dungeness	550 ,,	110

This downward trend arises from the growing familiarity of the nuclear power industry with the problems of nuclear plant design and construction and from better overall optimization of design. It is difficult to separate these influences when considering individual designs, but from the general picture presented by the nuclear stations now being constructed three distinct lines of advance may be seen. These are, first, an increase of pressure in the gas circuit, secondly, improved utilization of the volume of the pressure vessel and, thirdly, increase in temperature of fuel elements and coolant.

A higher gas pressure leads to improved heat transfer from the fuel elements (allowing more power to be removed for a given fuel temperature limitation) and reduces the power required by the gas circulators. The higher the pressure, therefore, the greater the power that may be drawn from a given reactor. The coolant gas pressures for the Central Electricity Generating Board stations and for Calder are shown in Table 2, together with the pressure vessel dimensions and plate thickness.

Table 2

Station	Coolant pressure (lb./sq. in.)	Shape of vessel	Size of vessel	Thickness of plate
Calder	100	—	—	2 in.
Berkeley	125	cylinder	80 ft. high × 50 ft. diam.	3 in.
Bradwell	132	sphere	67 ft. diam.	3 in. (some 4 in.)
Hinkley Point	185	sphere	67 ft. diam.	3 in.
Trawsfynydd	239	sphere	61 ft. diam.	3½ in.
Dungeness	268	sphere	62 ft. diam.	4 in. (some 4½ in.)

This marked increase in pressure is due to the use of thicker plate for the pressure vessel and to the use of internal insulation in the hot-top domes. The effect of this latter advance in design is shown in a comparison between the system pressures of Bradwell and Hinkley Point, which have vessels of the same diameter and plate thickness. The greatly increased pressure at Hinkley Point is the direct result of internally insulating the top of the vessel, thus reducing its temperature and allowing a higher design stress. The increase in plate thickness follows naturally from the growing experience of welding and testing thick plate. This experience may be expected to lead to consideration of even thicker plate in the future.

Directly connected with this is the choice of shape of vessel—cylinder or sphere. As the reactor itself is of cylindrical shape, it fits most conveniently into a cylindrical pressure vessel and uses the volume of the vessel to the best advantage. Unfortunately, the allowable pressure in the cylinder is less than that for a sphere of the same diameter and plate thickness, and there is therefore a contest between utilization of volume and pressure in the system. The 'reactor cylinder' which has to be fitted into the pressure vessel includes the core itself, a cylindrical space above it which is needed to manœuvre the fuel-handling gear, and the heavy structure needed for the support of the core. Considerable design effort has been put into this structure to reduce its size and give a better shape, and hence a better utilization factor. How successful these efforts have been may be seen in Table 3.

This table clearly shows the better utilization possible with a cylindrical vessel and the considerable

Table 3

Station	Utilization factor (vol. of core/vol. of pressure vessel)	Shape of vessel
Berkeley	0·437	cylinder
Bradwell	0·313	sphere
Hinkley Point	0·406	sphere
Trawsfynydd	0·419	sphere
Dungeness	0·442	sphere

improvements that have been made in volume utilization in the spherical vessel.

The upward trend in temperature-levels is the result of better understanding of the heat-transfer process and better optimization of station design to make best use of this in terms of plant efficiencies. As the systematic and random variations in fuel-element temperatures become better understood, it becomes possible to design for operation nearer the limit set by the properties of the fuel-element materials. In short, the 'margin of ignorance' is being reduced and used to advantage. This is reflected in higher gas temperatures and improved steam conditions, as shown in Table 4; it must be remembered, however, that there is little more to be gained in this direction.

Table 4

Station	Gas inlet temp. (deg. C.)	Gas outlet temp. (deg. C.)	High-pressure steam conds. (lb./sq. in./deg. C.)	Low-pressure steam conds. (lb./sq. in./deg. C.)
Calder	140	336	195/313	48/177
Berkeley	160	345	306/322	62/322
Bradwell	180	390	755/373	195/373
Hinkley Point	180	374	650/363	180/354
Trawsfynydd	202	399	962/382	304/368
Dungeness	250	410	1,403/393	575/395

All these developments help the nuclear station designer to move in the direction of obtaining more power from a given size of reactor and therefore to achieve a lower capital cost per kW. We may assess the results of his efforts in terms of reactor heat generated per unit volume of core. These 'heat densities' are set out in Table 5; they show clearly that the rate of development has been high.

Table 5

Station	Heat density	
	kW./cu. ft. of core	kW./cu. ft. of pressure vessel
Berkeley	10·21	4·46
Bradwell	10·77	3·37
Hinkley Point	15·09	6·13
Trawsfynydd	17·46	7·31
Dungeness	15·37	6·73

There can be little doubt that it would be possible to obtain 500 MW. of electrical power from a reactor of the Calder Hall type, using a pressure shell of about 70 ft. diameter with plate thickness about 4 in. At a time when the only operating experience is from the Calder Hall reactors with a capacity of 35 MW. electrical power, one shrinks from carrying the extrapolation in size so far, yet reactors with this capacity must be built in order to get the best results from the advanced graphite reactor and for comparative purposes a 500-MW. Calder type reactor should be considered. Using Calder Hall reactors of this size and assuming economies which can obviously be made in layout and general engineering of the stations, the capital cost should come down to about £100 kW., which should give a generating cost of around 0·52*d.* a unit.

The initial generating cost estimated for the advanced graphite reactor shows little, if any, immediate advantage over the Calder reactor developed in this way, yet all logic and history tells one that it is necessary to move forward to the type which gives a prospect of using higher temperatures. It is probable that, in these circumstances, there will be a period in which the two types overlap, and orders for advanced graphite reactor stations will be interspersed between orders for Calder type stations until ultimately the more technically advanced graphite reactor shows a clear advantage in operating cost over the older type. This would conform with practice in the conventional field, where advance to higher steam conditions has never implied that all new power plants used the most advanced conditions.

Based on these forecasts of development in design and downward trend of capital charges, estimates of fuel-element prices and operating charges, the cost of nuclear power has been forecast and is shown in Fig. 4. This figure also shows the forecast cost of conventional power and indicates that costs should break even between 1966 and 1970, depending on the load factor at which it is possible to operate.

It is disquieting, however, to compare the research and development effort which is devoted to bringing down costs in the two fields. In the conventional field, the available figures suggest that research and development costs are of the order of 5 per cent of the capital value of power plants built. Information is not available to determine the corresponding figure in the nuclear field but, if it is assumed that the cost of the nuclear sections (that is, the cost of the reactors and heat exchangers but excluding turbo-alternators and other conventional items) of the nuclear power plants built for the Central Electricity Generating Board in the years during 1965–75 is rather less than £50 million per annum, it seems improbable that research and development costs, if effort is maintained at its present level, are likely to be less than 30 per cent.

That research and development costs can be so high is easily understood when one considers the advanced gas-cooled reactor. It is probable that by the time the advanced graphite reactor goes into use, research and development expenditure on the development of the Windscale prototype will have been of the order of £30 million, and this is only one part of the effort required. It is unquestionably the logical step forward in British reactor technology, yet it is possible that the number of power stations built by the Generating Board to use this type of reactor will be less than ten.

By the mid-1970's, advance to higher temperatures and higher ratings is likely to make the introduction of another thermal reactor necessary. (This article does not consider fast-reactor development because it is felt that it is at present ancillary to the development of thermal reactors.) In the absence of developments which cannot at present be foreseen, it appears that we are reaching the limit of temperature and neutron intensity at which graphite can be used as an irreplaceable moderator, and that we shall be forced to types of reactor which make replacement or reconditioning of the moderator possible.

The high-temperature gas-cooled reactor which is at present in the project stage at Winfrith Heath (as a joint venture with other European countries) is an effort to meet the problem by using the graphite as the canning material for the fuel; it is thus replaced as the fuel elements are changed. Using enriched

uranium in ceramic form in a semi-homogeneous system (which is capable of breeding), this reactor should, if it is successful, make it possible to achieve temperatures exceeding 1,000° C. in the heat cycle.

If such a system, using a replaceable graphite moderator, cannot be evolved, the alternative would be to use heavy water as a moderator, so that radiation damage can be repaired or removed during circulation. At that stage it would probably be convenient to use steam instead of carbon dioxide as a coolant. American reactor development has generally been on the lines of water-moderation and cooling. As they make their way towards higher temperatures in the heat-cycle, they will probably be forced to use steam cooling instead of water cooling. If this happens and if British development takes the line suggested, the two streams of development, starting so far apart, will have flowed logically together.

Meanwhile, we are faced with the fact that if the present rate of technological progress in the nuclear field is to continue, there appears to be little prospect that research and development costs will fall; they are likely to remain at about 30 per cent of capital expenditure.

For how long can the electricity industry justify this? The rate of advance in the nuclear field was determined initially by effort which was part of, and was justified by, the defence programme. Remembering that the demand for electricity has a doubling period of ten years, that the total fuel requirements of the Generating Board (expressed as coal equivalent) are now 54 million tons a year and will rise to 90 million tons a year by 1970, and remembering that it is improbable that sufficient British-mined coal would be available to meet the Board's total fuel requirement by some date in the 1970's, it appears reasonable to aim at continuing the high rate of advance of nuclear technology to the point where nuclear power breaks even in cost with conventional power; we shall then have freedom to manœuvre in a three-fuel economy. After that date, which is not remote, it is surely reasonable to think that research on reactor technology should be justified by savings which can be expected to arise from its industrial application. It is interesting to speculate how much the downward trend in the cost of conventional power could be increased if it could attract as great a research and development effort as its nuclear rival. There is no suggestion that it should attract such expenditure, but it is suggested that re-deployment of research and development resources must be carefully considered and that this consideration will probably demand a changed distribution in a few years time.

It is possible that there is, to-day, a danger that the deployment of research effort can be distorted by development work directed to defence and paid for by defence funds. Although work in the defence field may be directed to a few major projects, the ancillary work is widespread; for example, the development of nuclear weapons has demanded and fostered intensive and expensive research in ion exchange, solvent extraction, fluorine chemistry, vacuum technology, the metallurgy of a wide range of metals, the development of high-speed digital computers and other things. All these developments find industrial applications, so that the 'hot-house' growth of technology in the defence field affects the rate of development in many industrial fields where application is possible. When this happens only in the limited time of a war, the effect is beneficial; when peace returns, the injection of defence technology into industrial practice is a useful stimulus. But since 1946 conditions have been such that a war-time rate of development has continued in defence and its many ancillary fields, and one wonders whether the injection of these developments into the industrial field has not over-stimulated some industries in a way that makes it hard to live with them, while diverting effort from others. To avoid this would be difficult; but, as the emphasis of defence development moves from one field to another (and, one hopes, is ultimately relaxed overall), it is possible and desirable to examine the rate of advance which has been induced, and to ensure that it is adjusted to what is economically justifiable and that it does not continue by pure habit at a rate which is artificially high.

FOOD AND ANIMAL PRODUCTION

A SESSION on "Food and Animal Production Overseas", arranged by Section M (Agriculture) of the British Association, was held in Cardiff on September 2.

Mr. J. H. Anderson, of the National Agricultural Advisory Service, presented a rather gloomy picture of the present position of "Food Production Problems of the Middle East"—low rainfall, uncertain time of onset of the spring rains and, when it did come in quantity, the flooding of large areas and soil erosion.

For example, it had been calculated that in Iraq some 170 million tons of soil was carried down in the Tigris every year. Soil destruction by arable cultivations only and by over-grazing are leading to a worsening of the position. The average size of the holdings is small; for example, 90 per cent of the farms in Egypt cover less than 3 acres. In many cases these provide only enough food for the occupiers and none to supply the rapidly growing urban population. Throughout the area higher education tends to be directed to law rather than to technical training for the agricultural advisory or even medical services, there being only about two medical practitioners for every 3,000 inhabitants. He proceeded, however, under various headings, to describe what is being attempted and what is further needed to improve these conditions. Except for Egypt, better land and water-use is required: afforestation is wanted on the mountains. In Syria some 30,000 trees, in addition to windbreaks, are being planted to hold the water. In the discussion afterwards, it was mentioned that very deep ploughing with tractors, rather than the present shallow cultivation with wooden ploughs, would allow the water to sink in rather than run off or evaporate. Mr. Anderson also pointed out that it is increase in yield per acre which is required rather than increase in cultivated area. For this purpose nitrogenous fertilizers are one of the chief requirements, but the cost of importation is too great; Iraq is, however, setting up a nitrogen plant. Except for Turkey, Israel and Egypt, new improved varieties

of crops with better yielding capacity are also required. Throughout the whole area, locust destruction is needed. Much more irrigation is required; great advances are being made in Israel, where it is hoped by 1975 to double the present area and triple the crop output. One problem with irrigation is increase in the salinity of the soil, some 70 per cent of the irrigated area in Iraq being more or less affected by this: research is needed in desalinating.

Livestock improvement is also wanted; except for Israel and Egypt, from cattle and buffaloes respectively, milk is in poor supply. To produce this, more feed from arable cultivation is necessary. In the other countries, the browsing goat is a useful source of milk supply. The need for tractors is great, but development in this respect is slow owing to the cheapness of labour. However, as pointed out in the discussion, tractors are necessary for deep ploughing on hard soil before the rains come. As in most places, a better system of agricultural credit should be made available to effect these improvements. Methods of helping the small farmer to accumulate capital were mentioned in the discussion on the paper by Mr. B. N. Chatterjee. Much could be done to improve food production in this area if the advisory services for farmers could be raised to a higher level and their personnel better trained.

Dr. J. Griffiths Davies, of the Australian Institute of Agricultural Science, gave an account of "Pasture Development of Tropical Australia". In the northern area the rainfall is a summer one, which ranges from 10 to 180 in. as one passes from the southern to northern tropics and from central to coastal areas. In general, the soil is poor and suffers from deficiency of nitrogen, calcium, phosphate and potash, as well as many of the trace elements too. Throughout most of the area cattle rather than sheep are the main product. Slides were shown of typical primitive vegetation areas and the methods used for their improvement. In areas of long dead grass, burning allows the young green shoots at the base to become available to cattle. In the acacia country, the bush is pulled over by chains between powerful tractors, piled, burnt and grass seed, such as that of Buffel and Rhodes grass, sown. One of the features of grass growth in tropical areas is the very rapid and luxuriant growth which occurs in the wet season; this, with the onset of the dry season, develops fibre and is low in protein and energy value for feeding purposes. During the discussion which followed, it was suggested that under such conditions the grass should be cut frequently during the wet season and made into silage for feeding during the dry season.

One of the main limiting factors for growth of grass throughout the tropical parts of Australia is the supply of nitrogen in the soil, and it is one of the most costly to apply, being about £39 per ton. Whereas in the south of Australia the application of phosphates and seeding with subterranean, strawberry or white clover supplies nitrogen for the grass, there are at present no suitable legumes for this in the northern areas; search for these is now in progress. Throughout the tropics, legumes, such as cow peas, etc., have been found for arable culture, but none suitable for incorporating into grassland has yet been used. Slides of some species which might prove suitable were shown; one came from Brazil and another from Guatemala. Various requirements are necessary in addition to their capacity for fixing nitrogen—a perennial character, palatability and non-toxicity for cattle. In addition to finding suitable species, there is also the problem of finding the right strain of organism to inoculate the seed. Slides were shown to illustrate the very large differences which exist in the growth of the legume due to this factor.

The importance of the problem is seen in the fact that there are some 90 million acres of poor soil in tropical Australia on which such legumes could be incorporated into the grassland.

Mr. B. N. Chatterjee, of the Department of Agriculture, Bihar, in his paper on "Animal Production and Fodder Resources in India", described the five main agricultural zones, conditioned mainly by rainfall and altitude, and compared the vast differences which exist between the level of nutrition of the people there and in the United Kingdom. Typical examples of some of the breeds of zebu cattle were shown. The two dairy breeds, the Sindhi and Sahiwal, are small, both in size and numbers, but they give reasonable quantities of milk. Some dual-purpose work-milk types exist, but for the most part the breeds in India are specialized for draught purposes. Buffaloes supply much more milk than cattle and their milk contains some 7·5 per cent of fat. Goats, too, are used widely as sources of milk and meat supplies.

Three main systems of animal husbandry exist. The State breeding farms form the main and practically the only source of livestock improvement. As was pointed out in the discussion, these are not large enough or numerous enough for the work that needs to be done in improving the milk yields of their cattle. The village farms, which are very small, provide little more than draft bullocks and barely enough milk for their own needs. Thirdly, there are the nomadic herdsmen, mainly with sheep and goats which are folded on crop residues and graze marginal land. For the most part, feed for animals is supplied from crop residues, many of which contain large quantities of fibre. The village grazing areas are overstocked and provide more exercise than nutrition. The growing of fodder crops and the making of silage for the dry season are badly needed, while the killing of the older cattle in necessary to allow of a higher nutritive level for those which have a productive value.

In the discussion which followed, it was pointed out that not only would the production of more milk in the villages and its collection by organizations in nearby towns such as that existing in Poona, be of advantage to the nutrition of the urban population, but also the weekly income derived from it would keep the villager out of debt, so that when his crop came to be harvested it would be his and not the moneylenders. Moreover, if more milk were consumed, it would have a sparing action on the need for cereals, and so some land could be released to grow fodder crops, after which the yields of cereals would be higher. In pig-feeding experiments in England, it has been shown that it requires some 5 lb. of cereals to produce 1 lb. live weight, whereas when a little animal protein such as milk is added, this is reduced to about 4 lb. The question of whether the essential amino-acids in animal protein could be added to extracted leaf protein is at present out of the question, owing to the high cost of the synthesized products.

During the course of the discussion, Prof. J. Grossman from Brazil gave a short illustrated account of

the agricultural zones there. The projects for irrigation in the highly populated areas were mentioned. The grassland areas in the south with a 60-in. rainfall could, with phosphates and clovers, produce suitable feed for cattle. While in the far south European breeds of cattle can be kept, farther north it is necessary to use zebu cattle. Recently, however, improved beef types which are tolerant of heat, such as the new Santa Gertrudis breed from Texas, have been introduced.

JOHN HAMMOND

GROWTH BY CELL DIVISION IN INSECT TISSUE CULTURE

By DR. B. M. JONES and I. CUNNINGHAM
Department of Zoology, University of Edinburgh

THE cultivation of insect tissues and cells, first attempted about fifty years ago[1], has been an unexpectedly difficult problem[2-4]. A method for the routine production of insect cultures in a medium that can be easily prepared, and the provision of adequate evidence of growth by cell division taking place in them as in vertebrate cultures, has not hitherto been available[4]. The delay in devising such a method arises largely from pioneer work having to rely on knowledge of the requirements that favour the growth of vertebrate tissue in culture[5]. Recently, however, encouraging results have been obtained in maintaining insect tissue in a physiological solution based on the composition of insect hæmolymph[6,7], which differs profoundly from that of the blood of vertebrates[8-11].

The purpose of this article is to describe briefly the results of an investigation undertaken to try to devise a method of producing insect tissue cultures in a routine fashion, and to evaluate in particular the extent and nature of growth by cell division in the cultures obtained. The work is based on the use of diapause pupæ of the silkmoth, *Philosamia advena*, as a source of ovarian tissue for explants, and of hæmolymph for inclusion in the culture medium. It so happens that development in these pupæ is arrested for about six months extending from the autumn to the early summer, a period that can be lengthened if need be by storing the pupæ continuously at 25° C. (ref. 12). The pupæ, in providing tissue in a more or less uniform state over such a long period, thus favour the design of a method of producing insect tissue cultures as required. So does the use of a medium that can be prepared easily. The one employed in the present work consisted essentially of salts, sugars and organic acids, based on previous work[6], lactalbumin hydrolysate ('Difco'), *TC* yeastolate ('Difco'), and pupal hæmolymph. The latter was preheated before it was added to the medium[6]. The usual precautions were taken in preparing hanging-drop cultures to ensure freedom from contamination. Streptomycin and penicillin were also added to the medium at 100 I.U. and 50 I.U. per ml., respectively (Table 1).

In the preparations incubated at 25° C., cells began to migrate from the explants on about the third day, and from the fourth to ninth days the cellular outgrowths spread extensively over the surface of the coverglass (Fig. 1). The medium was changed every fifth day. The cultures remained healthy for up to four weeks, and in appearance they resembled primary chick fibroblast cultures.

Table 1. COMPOSITION OF THE MEDIUM FOR THE CULTIVATION OF OVARIAN TISSUE OF THE DIAPAUSE PUPA OF THE SILKMOTH *Philosamia advena*

		Mgm./100 ml.			Mgm./100 ml.
A.	NaH_2PO_4	110	*D.*	Malic acid	60
	$MgCl_2.6H_2O$	300		Ketoglutaric acid	35
	$MgSO_4.7H_2O$	370		Succinic acid	6
	KCl	300		Fumaric acid	5·5
B.	$CaCl_2$	80	*E.*	*TC* yeastolate ('Difco')	100
C.	Glucose	70	*F.*	Lactalbumin ('Difco')	1,000
	Fructose	40			
	Sucrose	40			

The salts were dissolved in 30 ml. water; calcium chloride in 7 ml. water; sugars in 10 ml. water; organic acids in 5 ml. water and neutralized with potassium hydroxide. Lactalbumin was dissolved by autoclaving at 10 lb. pressure for 10 min. in 35 ml. water; *TC* yeastolate in 5 ml. water. The solutions were mixed, adding the calcium chloride last. *p*H was adjusted to 6·35 with 10 per cent potassium hydroxide, and then pre-treated hæmolymph was added, and finally antibiotics. See text for further information.

To permit an estimation of growth by cell division in the outgrowths, and to ascertain the nature of the cells involved, a technique was devised for making permanent stained preparations of cultures *in situ*. Adhesion of the explants and the outgrowths to the coverglass, an important requirement for carrying it out successfully, was greatly favoured by the presence of 10 per cent hæmolymph in the medium, and by inverting the culture chambers during incubation.

Examination of such preparations revealed that several kinds of cells originating from the different

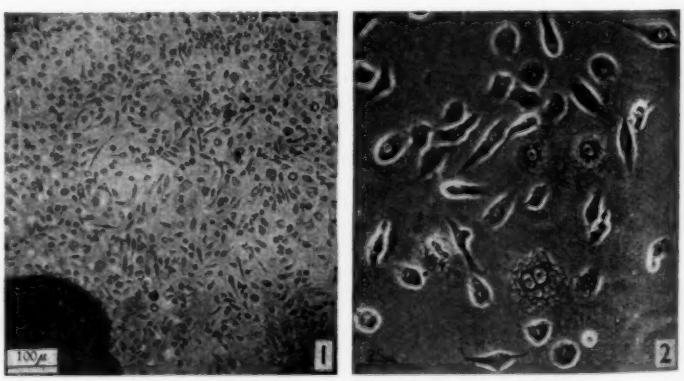

Fig. 1. Inner region of cellular outgrowth, eighth day *in vitro*

Fig. 2. Relatively large vacuolated cells derived from the ovariole sheath and other cells mostly from the intermediate layer of the ovariole present in cellular outgrowth, ninth day *in vitro*, phase contrast

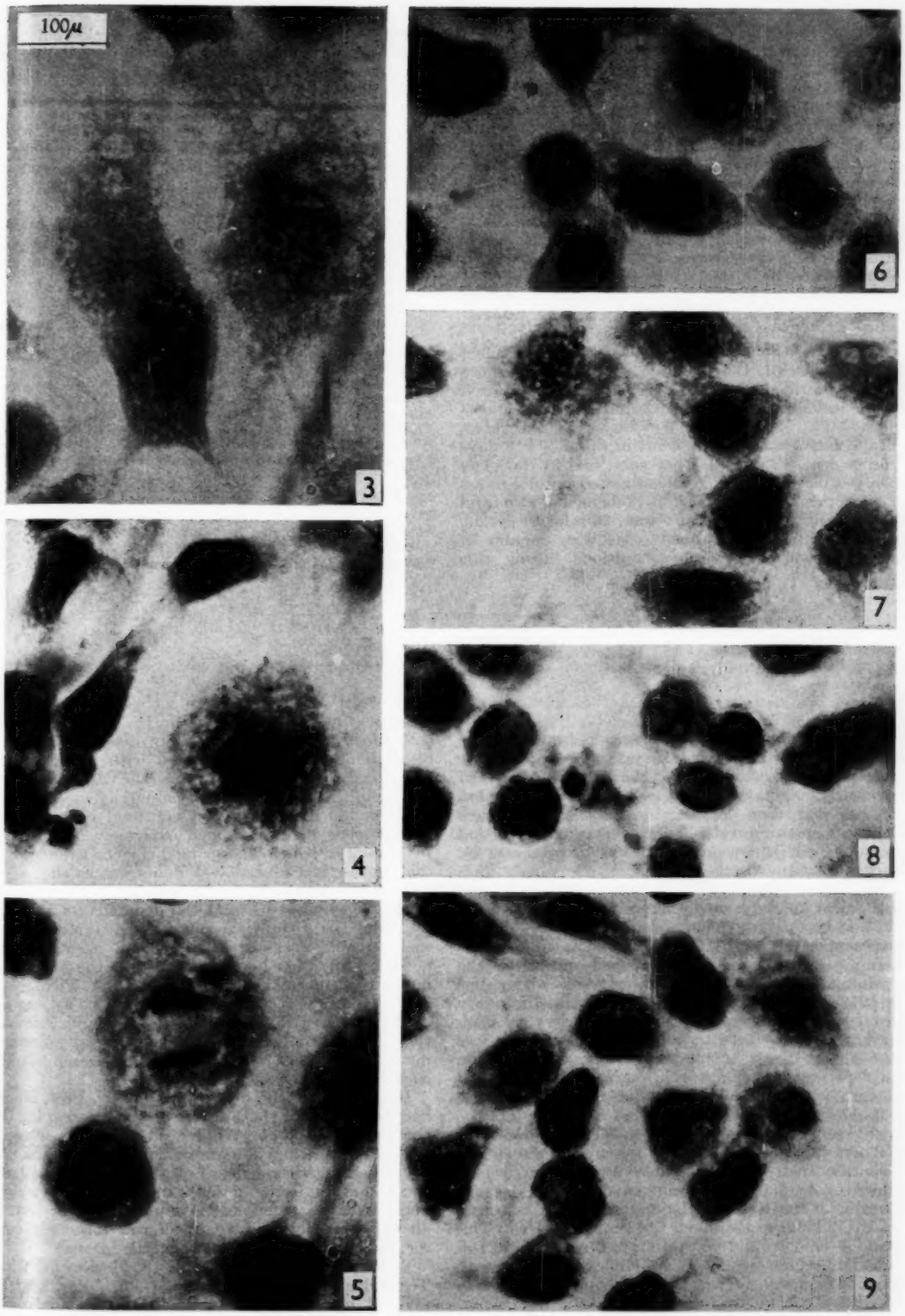

Fig. 3. Prophase in ovariole sheath cell in cellular outgrowth stained with Erhlich's hæmatoxylin *in situ*, 9 days. Fig. 4. Metaphase in same kind of cell in outgrowth, 9 days. Fig. 5. Late anaphase, 9 days. Fig. 6. Metaphase, 12 days. Fig. 7. Early anaphase, 12 days. Fig. 8. Telophases displayed by cells derived from the intermediate layer of the ovariole, 9 days. Fig. 9. Cells of intermediate layer in outgrowth almost completely divided, 9 days. (The number of days refers to age of culture)

regions of the ovary, long ago described in detail[13], were present in the outgrowths, those of the ovariole sheath and of the intermediate layer of the ovariole tubule being predominant (Fig. 2). It was less easy to be certain of the presence of cells of the inner follicle layer; but it is likely that these cells only escape into the medium when their bounding membrane is impaired in the explant. Occasionally, the extremely large nurse cells wandered out into the cellular field. Brush-like extensions composed of cells derived from the connective tissue cap, which encloses the distal portions of the ovariole tubules, and epithelial sheets formed by cells of the ovariole sheath, often appeared in the cultures prior to the migration of discrete cells. It has been suggested that hæmocytes might be present in the outgrowths[14], and it would be interesting to learn to what extent they are involved.

Mitosis in the outgrowths was mainly confined to the cells of the ovariole sheath, and those of the intermediate layer. These cells, scattered in the cellular field, displayed mitosis at all stages (Figs. 3–9). In cultures 5–6 days old the mean mitotic index was 1·0 per cent, in those of 8–9 days 0·5 per cent, 12 days 0·3 per cent, and 21 days less than 0·3 per cent. From an estimated mitotic index of 0·5 per cent over a period of 12 days, and also from the fact that cells in culture took 30 min. to divide, one may infer that the cells that were capable of mitosis produced several generations during this period. Mitosis in cultures three weeks old also supported the conclusion that growth by cell division was progressive and therefore resembled that which takes place in primary cultures of vertebrate tissue.

It is hoped to publish the details of this work, which was made possible by a grant from the Agricultural Research Council, elsewhere in due course. We thank Prof. Michael Swann for helpful discussions, Dr. Honor Fell for the interest she has shown in this work, Dr. John Campbell for taking photographs of mitotic figures in our preparations, and also Mr. Dennis Cremer for his help in the photography.

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OBITUARIES

Prof. H. Moore

Emeritus Prof. Harry Moore died on August 5 at the age of seventy-two. He was educated at Belle Vue School, Bradford, and the Royal College of Science, London, where he was afterwards demonstrator, and then lecturer, in physics at King's College, London, during 1908–15. During this period he published papers on the ionization produced by X-rays in various materials.

He was a very capable craftsman and he turned this talent to very good war-time use when during 1915–18 he was co-manager of the Munitions Training Department at King's College, London. There followed a short period as technical officer to the Training Department of the Ministry of Labour, but in 1919 he joined Sir Herbert Jackson in the newly formed British Scientific Instrument Research Association. It was here that his interest in glass was first aroused, and he was responsible with Jackson for a programme of research, particularly on optical glasses, which had originally been sponsored by a war-time Committee for Glass Research of the Institute of Chemistry. In 1933 he followed Sir Herbert Jackson as director of research of the British Scientific Instrument Research Association, a post which he held for four years, and in 1937 became director of the Research Laboratories then being set up by Pilkington Brothers, Ltd., in St. Helens. This post he held from 1937 until 1945, and during this time he became very active in circles concerned with glass technology, serving as president of the Society of Glass Technology during 1944–46.

Moore was appointed to the chair of glass technology in the University of Sheffield when W. E. S. Turner retired. The Department was set up in 1915 with the function of teaching in the subject of glass technology and with carrying out investigations and research on problems connected with industry. It was governed by a body known as the Glass Delegacy, the members of which were about equally divided between the University and industry. This unique arrangement had functioned extremely well during the period in which Turner held the chair, and while the number of University students was small. After the Second World War, the growth of the Department's teaching work and the demands on its time by industrial inquiries soon convinced Moore that some change in its structure would eventually be needed, and when he retired in 1955 the Delegacy, under the chairmanship of Dr. L. H. A. Pilkington, had just completed arrangements for the setting up of the new British Glass Industry Research Association. These arrangements left the University Department free to carry out teaching and research exactly as a normal university department.

In addition to the duties of his chair, Prof. Moore had been dean of the Faculty of Engineering for the three years, 1948–51. While head of the Department of Glass Technology, Moore's chief research work was concerned with the colours of glass and particularly those due to iron; a fascinating problem which, apart from its technological importance, for iron is an ever-present impurity in all raw materials used for glass making, has great scientific interest.

Shortly after Moore retired, the Society of Glass Technology found itself without an editor, and he allowed himself to be persuaded to step into the breach. Once having been persuaded, he threw himself into the task with characteristic energy and

attention to detail for a period of eighteen months. Towards the end of this period, however, he seemed to realize that he was no longer a young man, and after a short period in hospital, he and Mrs. Moore decided to move south and, as he himself put it, "to rusticate completely". In September 1958 they moved to Arundel, where his younger son had been living for a year or so. The move was a success and it is pleasant to think that he and Mrs. Moore had two years of quiet retirement together.

The University of Sheffield and the glass industry will always be conscious of the great debt it owes to Harry Moore for his energetic leadership and wise guidance of the Department of Glass Technology at a critical period of development and decision.

R. W. DOUGLAS

Walter Baade

WITH the death on June 26 of Walter Baade, astronomy loses a truly outstanding figure.

Some thirty years ago, it was generally expected that Baade would succeed to the directorship of one of the major German observatories. But this was not to be. In 1932, at the suggestion of Edwin Hubble, Baade was offered a two-year fellowship at the Mt. Wilson Observatory. His knowledge of astronomy proved so comprehensive, and his telescopic technique so perfect, that this temporary arrangement soon became permanent. Baade remained a staff member of the Mt. Wilson and Palomar Observatories until retirement two years ago.

At the time of his emigration, Baade was perhaps best known for his work on Cepheid variables. 'Baade's criterion' is still spoken of in the subject.

In a short space, only the briefest mention can be made of his outstanding contributions. There was work on supernovæ, first with Zwicky, then with Minkowski. Baade's supremacy as an observer was widely acclaimed after his brilliant resolution in 1944 of stars in the nucleus of the Andromeda Nebula. In his contribution to the dedication of the 200-in. Palomar telescope, he clearly foresaw the great contribution that the colour-magnitude diagrams of star clusters would make to the understanding of stellar evolution. Perhaps his most famous piece of work was his re-assessment, some ten years ago, of the distance scale of the universe. Outstanding in recent years has been the optical identification, in collaboration with Minkowski, of cosmic radio sources.

Almost every one of Baade's papers turned out to have far-reaching consequences; and much has died with him.

FRED HOYLE

NEWS and VIEWS

Biochemistry at Leicester : Prof. Hans L. Kornberg

DR. HANS L. KORNBERG, who has been appointed to the newly established chair of biochemistry at the University of Leicester, has distinguished himself especially by a series of papers on the metabolism of simple carbon compounds in micro-organisms. He has made major contributions to the elucidation of the pathways leading from acetate and more highly oxidized carbon compounds to cell constituents when such compounds serve as the sole source of carbon. Dr. Kornberg was educated at Queen Elizabeth Grammar School, Wakefield, and the University of Sheffield. He started his postgraduate career in the Department of Biochemistry at the University of Sheffield in 1949 after graduating in the Honours School of Chemistry. In 1953 he was awarded a Commonwealth Fund fellowship, which he spent in the laboratories of Dr. E. Racker of Yale University and the Public Health Research Institute of the City of New York, and of Dr. M. Calvin at the University of California. Since 1955 he has been a member of the staff of the Medical Research Council Unit for Research in Cell Metabolism at the Department of Biochemistry, Oxford, where he has headed a very active research group including many visitors from overseas.

Botany at St. Andrews : Prof. J. A. Macdonald

DR. J. A. MACDONALD has been appointed professor of botany at the University of St. Andrews in succession to Prof. J. H. Burnett, who is taking the chair of botany at King's College, Newcastle-on-Tyne (see *Nature*, **186**, 1016; 1960). The appointment of Dr. J. A. Macdonald, who is at present senior lecturer in the Department of Botany at St. Andrews, will bring pleasure to a wide circle of botanists, not least to those in Scotland. His appointment ensures the continued happy development of the department, and the Botanic Garden, much of which was initiated by him during 1950–55 as acting head of the department. Born at Dingwall, Dr. Macdonald was educated successively at Paisley, Inverness Royal Academy and the University of Edinburgh. He obtained the B.Sc. (Agric.) with honours in botany in 1931, and the Ph.D. in 1935. He was then appointed lecturer in botany at St. Andrews and senior lecturer in 1953; in 1947 he was awarded the Sykes Gold Medal for his D.Sc. thesis. Elected Fellow of the Royal Society of Edinburgh in 1940, he has served on the Council since 1956; during 1955–57 he was president of the Botanical Society of Edinburgh. Dr. Macdonald's special interests are in fungal cytology, the general biology and life-cycles of rust fungi and pathogenic fungi. He has brought to these studies the very needful qualities of healthy scepticism, great tenacity and patience. His work has stimulated interest in the somewhat neglected field of somatic fungal cytology. To his teaching Dr. Macdonald brings humour and good sense; to his University, loyalty and a wide acquaintance with university administration; to his colleagues and students, friendliness and understanding. He will take up his appointment on January 1, 1961.

U.K. Agricultural and Food Attaché in Argentina : Mr. A. G. Mill

MR. A. G. MILL, a livestock husbandry advisory officer of the National Agricultural Advisory Service, has been appointed agricultural and food attaché on the staff of the British Embassy in Buenos Aires, in succession to Mr. R. H. Smyth, who has retired. Mr. Mill was educated at Warwick School and Harper

Adams Agricultural College. During 1929–38 he worked for Liebig's Extract of Meat Co., in Argentina. He joined the Ministry of Agriculture and Fisheries in 1939 as a livestock officer. During 1945–49 he was loaned to the Colonial Office for service with the Government of Barbados. On his return to the Ministry in 1949, Mr. Mill was appointed agricultural attaché in Buenos Aires where he served until 1952, having led the United Kingdom delegation to the Inter-American and Food and Agriculture Organization Conference in Monte Video, Uruguay, in 1950. Since 1952 he has been a livestock husbandry advisory officer of the National Agricultural Advisory Service, stationed in the West Midland Region.

Future of Broadcasting in Great Britain

The Committee on Broadcasting under the chairmanship of Sir Harry Pilkington is ready to receive representations. The terms of reference of the Committee are: "To consider the future of the broadcasting services in the United Kingdom, the dissemination by wire of broadcasting and other programmes, and the possibility of television for public showing, to advise on the services which should in future be provided in the United Kingdom by the B.B.C. and the I.T.A.; to recommend whether additional services should be provided by any other organization, and to propose what financial and other conditions should apply to the conduct of all these services". Any person or organization desiring to submit evidence or to make representations to the Committee should address them in writing to the Secretary, Committee on Broadcasting, G.P.O. Headquarters' Building, St. Martin's-le-Grand, London, E.C.1, as soon as possible, but not later than November 30.

Electronic Equipment in the French Nuclear Energy Industry

No. 3 in the Review Series published by the International Atomic Energy Agency, Vienna, is entitled "Electronic Equipment used in the Nuclear Energy Industry in France" and is in French with English, Russian and Spanish translations of the introduction and table of contents. The authors, P. Desneiges, M. Doireau, L. Koch and J. Weill, are members of the staff of the Centre d'Etudes Nucléaires, Saclay, and the subject-matter refers particularly to French practice, though much is common to other countries and equipment similar to that described is available in many places. The four sections of the review deal respectively with basic electronics equipment for laboratories, such as rate meters, pulse-height analysers and personnel monitoring instruments, and their standardization; specialized equipment, including particle detectors of various kinds and complex electronic equipment for carbon-14 and tritium measuring techniques; reactor control equipment, including neutron detectors, amplifiers, servo-mechanisms and electronic computers; and special applications of nuclear electronics involved in prospecting for uranium minerals, the control of the chemical processing of plutonium and fission products and the detection of leakage of fuel containers. Details of circuitry are not given; but a comprehensive list of references at the end of the Review includes reviews covering specific aspects and a catalogue published by the French atomic energy authority which contains data on commercially available nuclear electronic instruments.

Report of the Government Chemist

The report of the Government Chemist for 1958–59 (London: H.M.S.O., 1960. 3*s*. 6*d*. net) contains accounts of a wide range of subjects studied during the period stated. The responsibility for this Laboratory, previously known as the Government Chemist's Department, passed from H.M. Treasury to the Council for Scientific and Industrial Research on July 1, 1959, and the report covers the period from April 1958 to December 1959. An interesting discovery is that of the poisonous alkaloid solanine in dangerous amounts in early new potatoes imported from the sub-tropics. The formation of persistent foams in sewage treatment and in rivers, resulting from the use of synthetic detergents, has been fully investigated and the report contains much information on this subject. The use of alternative material is likely to mitigate the trouble.

Accidents in Mines and Quarries

The annual reports of H.M. Divisional Inspectors of Mines and Quarries for 1959 (London: H.M. Stationery Office) for each of the eight divisions (Scottish, 3*s*. 6*d*. net; Northumberland and Cumberland, 2*s*. 6*d*. net; Durham, 3*s*. 6*d*. net; North Eastern, 3*s*. 6*d*. net; North Western, 3*s*. net; East Midland, 3*s*. 6*d*. net; West Midland and Southern, 3*s*. 6*d*. net; and South Western, 2*s*. 6*d*. net) have been published at intervals during the past few months. The reports deal with accidents and their prevention, dangerous occurrences, ventilation, safety organization, training, education, health and welfare in connexion with all mines and quarries in Britain. Most of each report concerns coal mines, with emphasis on accidents, dangerous occurrences and safety. Accident-rates, fatal and non-fatal, from all causes show improvements in some divisions, compared with averages for the past three years, but not in others. During 1959 the number of men killed in coal mines varied, among the divisions, from 0·47 to 5·03 per million tons mined, while the number killed per thousand workers varied from 0·18 to 1·13; the corresponding figures for serious non-fatal accidents were 4·62 to 15·01 and 1·97 to 3·17. Except in one division, where 47 men were killed in an underground fire, more accidents at coal mines were due, as usual, to falls of ground than to any other single cause and, over Britain as a whole, accounted for 142 deaths out of a total of 348 and for 710 serious non-fatal accidents out of a total of 1,676. Mining is hazardous; but it is clear from these reports that the accident-rates could be much reduced by adherence to rules and application of good sense.

Introducing Atomic Energy

A series of articles entitled "A Plain Man's Guide to Atomic Energy" is being contributed by P. J. Duncton, the director and general manager of (Heston) Fairey Engineering Ltd., to the quarterly magazine *Fairey Review*. In the first article an outline was given of the general structure of matter and the relationship between matter and energy, and in the second article which appears in the current issue (3, 36; June 1960) radioactivity and the release of nuclear energy are discussed. Reference is made to the classic investigations of the Curies, Rutherford, and Cockcroft and Walton, but the opportunity is taken to mention and to give illustrations of modern methods and equipment for handling and machining radioactive materials. A

coloured chart of the elements including all known isotopes, with stable and unstable isotopes and nuclear isomers shown separately, and with two typical radioactive-decay chains, accompanies the article. (Uncreased copies of the chart may be obtained from Fairey Engineering Ltd., 24 Bruton Street, London, W.1.) The third article in the series will deal with the interaction of neutrons with matter and the general economy of neutron production in a fission reaction.

Strontium released from the Windscale Accident

IT is perhaps surprising to find another publication on the Windscale reactor accident in October 1957. However, a recent joint report by the United Kingdom Atomic Energy Authority and the Agricultural Research Council, entitled "The Deposition of Strontium-89 and Strontium-90 on Agricultural Land and Their Entry into Milk after the Reactor Accident at Windscale in October 1957", provides a useful reassurance that radiostrontium from the reactor was probably not deposited on the ground in biologically significant quantities (Report AHSB (RP) R2. Pp. ii+26+5 plates. London: H.M. Stationery Office, 1960. 5*s*. net). The concentrations of strontium-89 and strontium-90 in herbage, root-mat, soil and milk are given in detail for no less than thirteen farms. Only for farms within a 2-mile radius of the factory was it possible to conclude that strontium-90 had come from the Windscale reactor. The highest value recorded, in a field adjacent to the pile, was some sixty times the national average, although a large proportion of the material on this field apparently resulted from emissions prior to October 1957. For farms at distances of 8–20 miles, it could not be established with certainty that the levels were measurably higher than for other parts of Great Britain, where all the strontium-90 is presumed to be the result of nuclear weapon testing. The highest concentration in any of the milk samples from the 'near-in' farms was 11 per cent of the maximum permissible level allowed by the Medical Research Council for reactor accidents. There is a further reassurance in evidence which suggests that the incorporation into food chains of radiostrontium released from the pile is only about one-third of that reported for bomb-produced strontium.

Helium-4 Scale of Temperature

AT the meeting of the International Committee of Weights and Measures held in Sevres, during September 29–October 3, 1958, the recommendation was adopted that the '1958 Helium-4 Vapour Pressure Scale of Temperatures', based on a vapour pressure table arrived at by international agreement and co-operation, should be used as the international standard scale of temperature between 1° and 5·2° K. A recent publication by F. C. Brickwedde, H. van Dijk, M. Durieux, J. R. Clement and J. K. Logan, issued by the U.S. National Bureau of Standards, describes the new scale in detail (Monograph No. 10. Pp. ii+17. (Washington, D.C.: Government Printing Office, 1960.) 20 cents). In Part 1 of the monograph, F. G. Brickwedde discusses the three practical methods for the determination of the helium-4 vapour pressure–temperature relation, and the various measurements made, and scales adopted, prior to 1958. Following discussions at Leyden between members of the Kamerlingh Onnes Laboratory and the National Bureau of Standards in June 1958, the Scale and the table of helium-4 vapour pressures later adopted by the International Committee of Weights and Measures were agreed on. The table was distributed at the Kamerlingh Onnes conference on "Low Temperature Physics" held at Leyden during June 23–28, 1958, and was published in the conference proceedings. The vapour pressures were listed at 1/100 degree intervals. The table has since been expanded by Clement and Logan, and the expanded table forms one of the seven tables presented in Part 2 of the monograph. In addition to the vapour pressure of helium-4 (1958 Scale) in microns (10^{-3} mm.) mercury at 0° C. and standard gravity (960·665 cm. sec.$^{-2}$) there are listed the 1958 helium-4 vapour pressure-temperature scale, T in deg. K. as a function of pressure P in mm. mercury, and, for $P > 80$ cm., in cm. mercury, at 0° C. and standard gravity; dP/dT in mm. mercury per deg. K.; an auxiliary table for use in making hydrostatic head corrections; deviations of earlier scales from the 1958 Scale; and an auxiliary table for use in making corrections for the density of mercury at temperatures other than 0° C. Fixed points on the '1958 Helium-4 Scale' are the boiling point at 4·2150° K. and the λ-point at 2·1720° K., for $P = 760{\cdot}00$ mm. mercury at 0° C. and standard gravity, and the critical point at 5·1994° K. if the critical pressure is taken to be 1,718 mm. mercury at 0° C. and standard gravity.

High-Temperature Furnaces

A NEW range of electric furnaces for use in the laboratory, workshop or tool-room is described in Messrs. A. Gallenkamp and Co. Ltd.'s catalogue No. 620 which has recently been issued. Operating temperatures have been increased and box and tube furnaces are now available for use up to 1500° C. The smallest muffle furnace, the 'Super Hotspot', is a moderately priced, versatile furnace for general laboratory work at temperatures up to 1100° C. The refractory muffle which is wound externally with a high-grade resistance-wire heater is fitted in a non-corroding 'Asbestolite' case of smooth surface by refractory insulating bricks. There are built-in controls and pyrometric equipment, together with a safety fuse to protect the heating element against accidental overheating. The larger muffle furnaces are available in three sizes, and together with the 'Super Hotspot', have internal sizes ranging from 4 × 5 × 6 in. to 8 × 9 × 18 in. The box furnaces are similar to the muffle furnaces, but with 'Crusilite' elements for temperatures up to 1400° C. and with 'super' elements (chiefly molybdenum disilicide) for temperatures up to 1500° C. Tube furnaces with 'Crusilite' and 'super' elements are also available. Two sizes, 4-in. diameter and 9-in. high, and 6-in. diameter and 15-in. high, of vertical-tube crucible furnaces have been introduced. They have wire elements wound on grooved refractory tubes and have built-in manual controls and temperature indicators. Other types of furnaces described in the catalogue include a high-temperature vacuum furnace, ash furnaces, and Gray-King furnaces for coal and coke analysis.

The Tungusska Meteorite

THE problematic Tungusska meteorite, which fell on June 30, 1908, is still a subject of discussion (V. N. Rodionov and M. A. Tzikulin, *Priroda*, **11**, 84; 1959). It is marked by an elliptical area of full tree-fall, 25 × 10 km., surrounded by a zone of a partial tree-fall, 50 × 40 km. As suggested previously, this devastation is due to the impact of the shock-wave,

as no fragments of meteorite itself were ever found. It is suggested by the present authors that the meteorite may have disintegrated and the fragments fallen in the front of the partial tree-fall. On the other hand, B. I. Vronsky (*Priroda*, **3**, 88; 1960) suggests, first, that the meteorite in question may have been a stone, and not an iron meteorite; and secondly, that the numerous water-logged hollows, so abundant in this area, may indeed represent impact craters of the meteorite fragments now deeply buried in the bog. Finally, E. L. Krynov, a foremost authority on meteorites (*Priroda*, **5**, 57; 1960), does not agree with either view and is inclined to accept the hypothesis originally advanced many years ago by I. S. Astapovich and F. L. Whipple (*Priroda*, **9**, 70; 1935), who have suggested that the Tungusska tree-fall was not due to the impact of a meteorite, but of a small comet containing a core of ice which had embedded in it meteoric matter.

Dispersion of Small Bodies

Dr. D. O. Wolfenbarger has prepared a scholarly review of the dispersion in space of small bodies (*Lloydia*, **22**, No. 1, 1; 1959). In this paper he covers work published since the appearance of his earlier account, published in 1946. His aim has been to describe and analyse quantitative and objective results published on this topic. This is done with the help of 194 graphs which accompany the examples discussed. The types of unit dealt with are inorganic salts, viruses, fungi, pollen, molluscs, water-fleas, and insects, including grasshoppers, mosquitoes, flies and bees. The agents of dispersal include air currents, water, other organisms, growth, and automotility. The distances involved extend from less than 1 mm. from the source, reached by basidiospores of *Puccinia malvacearum*, the principal agent being gravity, up to the 140 miles covered by some tsetse flies by means of hitch-hiking on trains. In a discussion of the results, Dr. Wolfenbarger considers the achievements of dispersion in the biology of organisms, the details of sampling and measuring, and the endogenous and exogenous factors associated with varying distances of dispersion. There is much in this review that is relevant to plant, animal and human epidemiology, allergy, population genetics, plant breeding, and plant and animal ecology.

Search for Oil in Britain

In 1937, G. M. Lees and P. T. Cox described a geological basis of oil prospecting in England as then envisaged. This was followed by a report on exploratory work by G. M. Lees and A. H. Taitt (1946), wherein particulars were given not only of the discovery of four new oilfields, but also of new geological information of high academic and economic significance. The search still goes on. A recent Memoir (1960) of the Geological Society, by N. L. Falcon and P. E. Kent, presents geological results of petroleum exploration in Britain by the British Petroleum Company during the years 1945–57 (Memoir No. 2: Pp. 56+5 plates. (London: Geological Society of London and H. K. Lewis and Co., Ltd., 1960.) 25*s*. net). Altogether eleven oil-producing areas have been established, with a cumulative production total, to the end of 1959, of more than 1·25 million tons. The latest fields are Plungar (Leicestershire) and Egmanton (Nottinghamshire); prospects are at Bothamsall, an extension of Eakring (discovered in 1939), and at Corringham, near Gainsborough. Other possibilities have been and are being pursued in which the well-tried techniques of reflexion seismic exploration and electric logging have been successfully exploited. It is noteworthy that gamma-ray logging proved to be of considerable help in sub-surface correlation of marine-band markers in the East-Midlands projects. Economically important also is that the pattern of oil prospecting as originally delineated has been extended to include search for natural gas, jointly on behalf of the Gas Council and Imperial Chemical Industries, but with what measure of commercial success has yet to be determined.

Freeze-drying of Plant Viruses

Whereas freeze-drying has been widely and successfully used for the preservation of bacteria, animal viruses and bacteriophages, there appear to have been relatively few attempts to conserve viruses by this means. It has been ascertained that some plant viruses retain their infectivity for long periods in frozen tissue or sap, or in plant tissue frozen and slowly dried over calcium chloride. Such procedures, however, are not suitable for preserving some labile and certain other viruses. M. Hollings and R. A. Lelliot (*Plant Path.*, **9**, No. 2, 63; 1960) have now described effective methods for the freeze-drying of a considerable number of viruses. The preservation of sap preparations of forty-six isolates of thirty-nine plant viruses by the rapid sublimation of water from frozen suspensions and subsequent storage under vacuum (freeze-drying) was investigated. Infective virus was recovered from preparations of all strains, except one of potato virus *A*, after freeze-drying and after storage during periods varying from four to eleven months. It appeared that the spherically shaped viruses studied lost little or no infectivity during freeze-drying, but that several of the rod-shaped viruses lost much of their infectivity. There was no evidence of further serious loss of infectivity in forty-five of the preparations during the storage period.

Lalor Grants and Awards for 1961

The Lalor Foundation has announced the programme of awards for 1961 which it is offering for support of research on the fundamental biochemical and physiological mechanisms concerned with fertility and the early stages of reproduction in various forms of life. The objectives are to further the knowledge and understanding of the basic phenomena involved and to extend and develop the possibilities for effective regulation and control. The awards may range up to 8,000 dollars a year, depending on the scope and duration of the project approved. Preference will be given to younger members of university and college faculty and staff, with an upper age limit of 41 years. The work may be carried on at the applicant's own institution or elsewhere. The Foundation will also grant post-doctorate summer or short-term research awards at the Marine Biological Laboratory at Woods Hole, Mass., or elsewhere for appropriate projects in the fields specified. For these awards, the stipends will normally not exceed 1,000 dollars for a single man or a woman, 1,200 dollars for a married man working at his home institution, and 1,350 dollars for a married man with principal programme at another institution. A number of these awards may be granted to nationals other than citizens of the United States, usually under the condition that the award holder's

work shall be conducted at an American institution. Applications and inquiries should be sent to the Lalor Foundation, 4400 Lancaster Pike, Wilmington 5, Delaware, and applications must be received by January 16, 1961.

Non-Destructive Testing of Materials

THE British Council is organizing a course on the non-destructive testing of materials in London for two weeks beginning October 16. The course is designed for overseas industrial technologists and scientific research workers. Its aim is to provide them with a broad survey of work in progress in the United Kingdom on the development of non-destructive testing techniques and the uses to which these techniques are being put by industry. The course will consist of lectures, discussions and visits. The main emphasis will be on the scientific background. The inclusive fee for this course, which is residential, will be £47. Further information can be obtained from Miss B. Sinclair, The British Council, 65 Davies Street, London, W.1.

The Leopoldina German Academy of Sciences : Elections

THE Deutsche Akademie der Naturforscher Leopoldina, Halle, recently elected the following new members, among others, in the sections indicated : *Physics*, Prof. Hans Kopfermann (Heidelberg) ; *Geophysics*, Prof. Alfred Ehmert (Göttingen) ; *Chemistry*, Prof. Horst Böhme (Marburg), Prof. Harry J. Emeléus (Cambridge), Prof. Gunnar Hägg (Uppsala), Prof. Karl Myrbäck (Stockholm), Prof. Linus Pauling (Pasadena), Prof. Tadeusz Urbański (Warsaw), Prof. K. Venkataaraman (Poona) ; *Botany*, Prof. Rudolf Mansfeld (Gatersleben).

The Night Sky in October

FULL moon occurs on Oct. 4d. 22h. 17m. U.T., and new moon on Oct. 20d. 12h. 03m. The following conjunctions with the Moon take place : Oct. 9d. 09h., Aldebaran 0·3° S. ; Oct. 11d. 22h., Mars 5° N. ; Oct. 22d. 21h., Venus 6° S. ; Oct. 24d. 22h., Jupiter 5° S. ; Oct. 25d. 21h., Saturn 4° S. In addition to these conjunctions with the Moon, Venus is in conjunction with Antares on Oct. 28d. 20h., Venus being 3° N. Mercury and Venus are too close to the Sun for observation. Mars rises at 21h. 15m., 20h. 50m. and 20h. 10m. at the beginning, middle and end of the month, respectively. It is in Gemini, and is a very prominent object, of magnitude + 0·1 on October 15, when its distance from the Earth is 88 million miles. Jupiter sets at 20h. 50m., 20h. 05m. and 19h. 15m. on October 1, 15 and 31, respectively. It is in Sagittarius, and may be seen low in the south-west after sunset, but conditions are not favourable for observation. Saturn is in Sagittarius, east of Jupiter, and sets at 22h. 00m., 21h. 10m. and 20h. 15m. at the beginning, middle and end of the month, respectively. Its stellar magnitude is + 0·7 and its distance from the Earth on October 15 is 940 million miles. There is one occultation of a star brighter than magnitude 6 visible at Greenwich : Oct. 9d. 0h. 24.9m., γ Tau. (*D*) ; Oct. 9d. 1h. 41·7m., γ Tau. (*R*). *D* and *R* refer to disappearance and reappearance, respectively. The Giacobinids are active on October 9, but conditions are unfavourable, and little activity is expected. The Orionids are active during the third week of the month, conditions being favourable ; the radiant is near R.A. + 6h. 24m., Dec. +15°.

Announcements

DR. G. JONES, of the Rowett Research Institute, Bucksburn, Aberdeen, has been appointed to hold the Sophie Fricke Royal Society Research Fellowship in the Rockefeller Institute for the academic year 1960–61. Dr. Jones will leave the United Kingdom in October for the Rockefeller Institute, where he will be working on the fractionation and characterization of leaf proteins.

SIR WILLIAM SLATER, until recently secretary of the Agricultural Research Council, has been appointed chairman of the governing body of the Glasshouse Crops Research Institute in succession to Mr. T. Ainslie Robertson.

MR. V. CORY, at present deputy county advisory officer in the National Agricultural Advisory Service, Essex, has been appointed county advisory officer for Yorkshire (West Riding) in succession to Mr. J. Gibbons, who has been appointed county advisory officer for Somerset. Mr. Cory will take up his new post on October 3.

THE Association of British Chemical Manufacturers, 86 Strand, London, W.C.2, has published a booklet entitled "Chemical Plant Instrumentation. Some Notes on the Use of Measuring Instruments" (6*s*. to members ; 7*s*. 6*d*. to non-members, post paid). The nine topics covered in some fifty pages include temperature and pressure measurement, gas chromatography, continuous gas analysis by infra-red, glass electrode *p*H-meter and smoke-density meters. The information will be of interest to the managements of industrial firms.

THE Institute of Physics and the Physical Society is arranging a conference on statistical mechanics (with special reference to irreversibility), to be held at Queen Mary College, London, on December 19 and 20. Further information can be obtained from the Secretary, Institute of Physics and the Physical Society, 47 Belgrave Square, London, S.W.1.

THE annual meeting of the Physical Chemistry Society of France will be held at l'Hotel du Col de Voza, Chamonix-Mont Blanc (Haute Savoie), during June 26–30, 1961. The subject of the meeting will be "The Structure, Synthesis and Function of Deoxyribonucleic Acid". Further information can be obtained from the Secretary, Société de Chimie Physique, 10 Rue Vauquelin, Paris V^e.

THE AGARD Avionics Panel has arranged a symposium on "Radio Navigation" in conjunction with the Tenth AGARD General Assembly during October 3–9 in Istanbul. The proceedings will cover general problems concerned with navigation, including papers on wave-propagation, radio-navigation including Doppler and air-traffic control, space and astro-navigation and display methods and automatic approach and landing. Further information can be obtained from the Advisory Group for Aeronautical Research and Development, Organisation du Traité de l'Atlantique Nord, 64 rue de Varenne, Paris 7ème.

ERRATUM. Writing in connexion with the communication entitled "Staining for Iodine in Chromatograms of Human Plasma" in *Nature* of August 20, p. 691, Dr. J. D. H. Slater states that the limit of sensitivity quoted as 0·2 μgm./100 ml. should have been 2·0 μgm./100 ml. (line 19, p. 692). The authors have since developed a considerably more sensitive technique.

THE CHEMISTRY OF NATURAL PRODUCTS

IN the Great Hall of the University of Sydney on August 25 Sir Kenneth Street, Lieutenant-Governor of New South Wales, formally closed the ten-day Symposium, entitled "The Chemistry of Natural Products", which had been opened on August 15 by Sir John Eccles, president of the Australian Academy of Science, in the Wilson Hall of the University of Melbourne. The meeting had made history as the first outside Europe and North America to be sponsored by the International Union of Pure and Applied Chemistry. Some 150 chemists from 33 countries, together with more than 200 Australians, attended as registered members. From overseas, Prof. A. Stoll (Switzerland), past president of the International Union of Pure and Applied Chemistry, represented the present president, Prof. W. A. Noyes, jun. The United Kingdom delegates were led by two Nobel laureates, Sir Alexander Todd and Sir Robert Robinson. Prof. R. Kuhn, also a Nobel laureate, due to arrive from Heidelberg, was unfortunately absent through illness.

The Symposium has differed from those hitherto held in other countries in that it was not located only in one city. It began in Melbourne in the State of Victoria, where it remained during August 15–18, then migrated about 300 miles to Canberra in the Australian Capital Territory, and finally shifted another 200 miles to Sydney; these movements all being made by air.

The Symposium was organized by the Australian Academy of Science, and the choice of subject was logical because the investigation of the constituents of Australian plants has formed the longest continuing organo-botanical-chemical research endeavour of scientists in Australia during the past century. In a sense its origin can be said to lie with Dr. John White, surgeon-general to the 'first settlement', who—soon after 1788—ran out of English peppermint oil, and discovered that an efficient substitute could be obtained by distillation of the leaves of the eucalyptus growing around Sydney Harbour. Prof. John Read (one-time professor of organic chemistry in the University of Sydney) devoted a whole chapter of his "Humour and Humanism in Chemistry" to this and subsequent periods under the title: "Chemistry Reaches the Australian Bush". Half a century ago the pioneering investigations of Smith and Baker (in what is now the Sydney Museum of Applied Arts and Sciences), followed later by those of Read himself, and Penfold (for many years director of the Museum) and others, have given Australia a significant place in essential oil and terpene research.

Alkaloids were first extracted from Australian sources in 1861. Shortage of certain drugs during the Second World War, and the problem of stock poisons occurring in plant foods, have caused a more intensive and systematic examination of Australian flora, and have led to the setting up of a phytochemical survey; this has stimulated much research in university and government laboratories, and brought to light many novel colouring matters, glycosides, alkaloids, toxic or pharmacologically active compounds, etc., which were reported during the Symposium.

The scientific proceedings were divided into four sections, namely: (*A*) Aliphatic and Homocyclic Chemistry; (*H*) Heterocyclic Chemistry; (*B*) Biological Chemistry; and (*P*) Physical Methods. Owing to the large number of papers submitted, the first three sections unfortunately (for the chemists interested) ran as concurrent sessions. Pillars in the construction of the programme were 14 lectures, attended by the whole assembly. At the opening ceremony, Prof. A. Stoll (Switzerland) spoke on "Impact of Studies of Natural Products on Chemical Industry". Three symposium lectures were delivered as follows: Section *A*, Prof. F. Šorm (Czechoslovakia), "Terpenic Compounds with Medium-Sized Rings"; Section *H*, Prof. R. B. Woodward (United States), "The Total Synthesis of Chlorophyll"; and Section *P*, Dr. H. W. Thompson (United Kingdom), "Physico-Chemical Methods of Studying Natural Products". Prof. Kuhn's eagerly awaited "Chemistry of the Gangliosides" had perforce to be omitted. Eight section lectures, also attended by all delegates, were: Section *A*, Prof. D. H. R. Barton (United Kingdom), "Some Aspects of Terpenoid and Steroid Chemistry", and Prof. N. A. Sørensen (Norway), "Structural Patterns of Polyacetylenic Compounds isolated from the Plant Family Compositæ"; Section *H*, Prof. H. Brockmann (West Germany), "Chemistry of the Actinomycins", and Prof. T. R. Govindachari (India), "Recent Investigations on Some Alkaloids from Indian Plants"; Section *B*, Dr. J. W. Cornforth (United Kingdom), "The Biosynthesis of Poly*iso*prenoids", and Prof. E. Lederer (France), "Chemistry and Biochemistry of Biologically Active Bacterial Lipids"; Section *P*, Prof. C. Djerassi (United States), "Application of Optical Rotatory Dispersion Studies to Problems in Natural Products Chemistry", and Dr. A. McL. Mathieson (Australia), "The Direct Determination of the Molecular Structure of Natural Products". Dr. J. R. Price (Australia) gave a special lecture entitled "Australian Natural Product Research".

Sir Alexander Todd, as president of the Symposium, gave as his presidential address in the new Academy headquarters in Canberra a general review, coupled with a plea that biochemistry must bridge biology and organic chemistry, by studies of function and structure, if it is to make its most successful contribution to knowledge. He spoke on "Natural Product Chemistry—Retrospect and Prospect".

Sir Robert Robinson summed up the scientific achievements of the Symposium at its closing ceremony. He said: "It would be presumptuous for me, or anyone else for that matter, to pretend to be able to perform adequately the task which I must now attempt. For one thing, none of us has been able, as we might have wished, to be in three places at the same time. Furthermore, the printed abstracts are largely of the nature of appetizers, an invitation to the lunch, but with a masterly reticence with regard to the menu, to say nothing of the details of the cooking". . . . "For me it has been throughout

an entrancing and spectacular display of progress and promises of future advances". Sir Robert specifically referred to Dr. Thompson's lecture, saying that although Thompson himself was a pioneer of infra-red spectroscopy he "gave pride of place to X-ray crystallography, because this method gives full structural information—not only that, but also solves the stereochemical problems". Sir Robert proceeded to note the part taken by Djerassi's work on optical rotatory dispersion, by mass spectrometry and by nuclear magnetic resonance, as well as by infra-red and ultra-violet spectra, in the discussions and lectures of the Symposium. He warned, however, that the classical organic chemist is certainly not to be displaced by machines . . . there is no need to discuss whether an absorption band is due to N—H or O—H if the compound does not contain nitrogen, "even if we know the structure we still have to explore the surrounding chemical territory . . . would it be good for organic chemistry as a whole if the structure of indigo had been solved by looking at a few milligrams of it, and if Baeyer had not carried out any of his wonderful work which led to the determination of its formula ? I think not !"

He went on : "We were greatly privileged to hear the lecture by Prof. R. B. Woodward, in which he described, I believe for the first time, the outstanding achievement of the total synthesis of chlorophyll. Prof. Woodward is not only a most brilliant synthetic organic chemist, but also an expositor, able to convey a sense of the drama of development to his audience. His lecture was thoroughly enjoyable, even thrilling as an experience. No doubt in places he admitted to a little good fortune, but he also made it clear it was expected. I was reminded of Benjamin Franklin's 'Luck is the bonus that accrues to industry'. Woodward and his team were surely industrious".

"This achievement of the synthesis of chlorophyll is a very good example of the kind of thing which one is often asked about . . . What good is it ? Of course, the good that it is, is the new knowledge which is obtained . . . the new knowledge of the behaviour of chlorophyll, the nature of the molecule, how it is likely to behave in other circumstances. . . . That new knowledge may lead us we don't know where".

About Prof. Lederer's lecture Sir Robert said : "It was quite outstanding in interest and importance. I had no means for measuring decibels of applause or its duration, but it was clear my assessment was widely shared. Lederer described extensive studies on biologically active bacterial lipids. . . . He explained in full the problems which had been finally solved, and even more useful, he indicated the stages reached in the solution of others, including some which may have great significance for the therapy of tuberculosis in the future. Lederer's mastery and humorous style charmed us. His contribution will certainly be remembered".

He continued : "Another aspect which has been running through the Symposium is that of biogenesis and structural relations, and the use of isotopic tracers to test the various hypotheses advanced in this connexion. . . . I think the lecture by Dr. J. W. Cornforth was an extremely important event in the conference—one of the real highlights. The way in which Cornforth was able to describe the complete story for the synthesis of poly*iso*prenoids was quite remarkable. It was . . . a lecture of great value to all of us".

Sir Robert then referred in terms of praise to all the other lectures mentioned above, to the "infectious enthusiasm" of Erdtman, the "brilliance" of Barton, Šorm and Brockmann, the many valuable and novel facts presented by Sørensen, Govindachari and Mathieson, impossible to summarize in the detail they deserve. Concerning Prof. Stoll's review of the impacts which natural product research has on industry, Sir Robert said : "These reverberations are important . . . Stoll's work is as academic as anyone else's . . . he has made extraordinarily valuable and neat contributions to the chemistry, for example, of the digitalis and ergot series". These have not been without profit in all senses of the word. Sir Robert paid a tribute to the survey of past and present Australian work by Dr. Price in his special lecture, and to the results presented by Price and collaborators in papers to Sections *H* and *P*. These, he said, showed how many opportunities exist in Australia for natural product research, and how beneficial has been the guidance of Dr. Price and his associates in the laboratories of the Commonwealth Scientific and Industrial Research Organization.

Sir Robert concluded : "Possibly the outstanding scientific value of the Symposium has been the opportunity it has afforded for the meeting of colleagues from all over the world for discussions . . . not only in the lecture theatres, but also in other places where we meet and talk together. . . . It has been the most outstandingly successful symposium I personally have ever taken any part in. I have never experienced a symposium in which so many papers of the greatest possible interest have been delivered . . . and I must say that I think it is due to the enthusiastic coming together of organic and physical chemists in the past twenty years, from which union we have gained advantages of powerful procedures . . . of chromatography, ordinary and vapour phase, of micro methods of analysis and of manipulation, of the many physical ways of examining products, of the availability of isotopes, and the techniques for handling them, and from which we can still see further new methods developing on the horizon . . . all this has made the Symposium a most significant occasion. We hope to repeat it in Czechoslovakia in 1962".

Sir Robert then spoke with appreciation of Sir Alexander Todd's services as president of the Symposium—this was received with great applause—and the meeting was closed by Sir Kenneth Street.

Officially the planners received strong support in high places. His Excellency the Governor-General of Australia, Viscount Dunrossil, was patron-in-chief, and Their Excellencies the Governors of New South Wales and of Victoria were patrons.

Official receptions were given by the Premiers of Victoria and New South Wales in Melbourne and Sydney respectively, and by the Prime Minister in Canberra. Immediately prior to the opening, Sir Alexander Todd received the honorary degree of doctor of laws from the University of Melbourne, and on August 24 the University of Sydney conferred on Sir Robert Robinson (first professor of organic chemistry in Sydney) its D.Sc. (*honoris causa*).

A full programme of social events and excursions for members and their ladies was also carried through. Outstanding were the Government receptions, the banquet in Canberra, a 'wine and cheese tasting' in Sydney by courtesy of the Australian Wine Producers' Association of New South Wales, and a fashion parade in Melbourne of Australian

woollens, arranged by the Australian Wool Board. The last two, together with the many scenic tours possible from the three centres, proved of great interest to visitors who had not previously seen the Australian way and place of life. Post-Symposium tours to north and south Queensland and to New Guinea are now in progress—the last-named being for men only and at the invitation of the Commonwealth Government and the New Guinea Administration.

The lectures mentioned above will be published through the Publications Committee of the International Union of Pure and Applied Chemistry by Butterworth's Scientific Publications, London.

R. J. W. Le Fèvre

WARREN SPRING LABORATORY

In planning the Warren Spring Laboratory at Stevenage, the Council for Scientific and Industrial Research decided that it should be a versatile station free to carry out research which cannot be fitted into the programme of another research body, especially work involving pilot-scale investigations of any subject of national importance.

As a result, the Laboratory's research programme includes a number of important investigations in several different fields*.

In chemical engineering, for example, the work is concerned mainly with providing the chemical plant designer with basic information. Considerably more knowledge is required to achieve greater precision in design work. The basic programme is confined to the study of mass transfer in gas–liquid systems, and these investigations will provide data for the precise design of large-scale equipment without the need for costly pilot-plant studies. For example, the investigation should enable more accurate prediction of the performance of gas–liquid contacting equipment to be made and thus facilitate the design of equipment such as distillation columns and gas absorption towers.

Much of the work of the Mineral Processing Division is undertaken for mining companies and other organizations, on repayment. Three main subjects of basic research are being studied: (*a*) grinding in the presence of additives such as surface-active agents; (*b*) the composition of surface minerals and the kinetics of bubble attachment to mineral surfaces; (*c*) the behaviour of mineral particles in a high-tension field and the modifications of this behaviour by various surface treatments. There have been indications during the year that automation may become important in mineral processing plants and an experimental programme is being considered.

In the Process Development Department, work has continued on the Fischer–Tropsch synthesis, which provides a method of obtaining liquid and gaseous fuels from carbon monoxide and hydrogen, which are produced by the complete gasification of low-grade high-ash coal. Basic research on catalysis has included work on the catalytic and other physico-chemical aspects of fuel cell operation.

A small human sciences research team is being formed at the Laboratory, and the Human Sciences Research Sub-committee, under the chairmanship of Mr. H. Briggs, labour adviser to Unilever, Ltd., is now considering the programmes of research in this increasingly important field.

Current research into air pollution concerns both methods of abatement and assessment of atmospheric pollution throughout Britain, with relation to the effects of clean air legislation. Estimates made during the year have shown that, in general, smoke from the burning of industrial coal has ceased to be a serious problem although in some instances it creates a local nuisance. The Laboratory has co-operated with the Port of London Authority and owners of tugs in demonstrating methods of reducing smoke emission from ships in coastal waters.

Smoke from Diesel exhausts provides another research problem. While a well-maintained and correctly operated Diesel vehicle need never produce black smoke, the fact remains that large numbers of lorries frequently do. Methods of removing smoke from exhaust gases are being studied. A 10-ton Diesel lorry fitted for road tests with various proprietary devices is being used for this purpose.

The Laboratory has continued to collaborate with local authorities on the measurement of pollution, and this is providing "a wealth of background information against which future improvements can be assessed".

Methods of measuring low concentrations of oxides of nitrogen (known to be emitted by practically all fuel-burning appliances) are being examined. These emissions may be significant factors in air pollution.

* Report of the Warren Spring Laboratory, 1959. Published for the Department of Scientific and Industrial Research. (London: H.M. Stationery Office, 1960.) 3*s*. net.

U.K. ATOMIC ENERGY AUTHORITY

The sixth annual report of the Atomic Energy Authority, the first to appear over Sir Roger Makin's signature and also the first to be submitted to the Minister for Science, covers the period April 1, 1959–March 31, 1960*. During that year, those major projects undertaken primarily to support the defence programme were completed, and all main plants constructed for that purpose were operating successfully. New capital projects approved during the year were on a relatively small scale. The Authority continued to devote a major effort in support of the civil power programme of the Central Electricity Generating Board and the South of Scotland Electricity Board. The report includes as an appendix the observations of the Minister for Science, in con-

* United Kingdom Atomic Energy Authority. Sixth Annual Report for the period 1st April, 1959–31st March, 1960. Pp. vi+72+4 plates. (London: H.M. Stationery Office, 1960.) 5*s*. net.

sultation with the Authority, on the fifth report of the Select Committee on Estimates on the Authority's Industrial Group. These comments have now been transmitted to the Committee.

Generally, the Authority welcomes the report and has accepted and will implement most of its recommendations. On the remaining recommendations, it is commented that the Authority has reviewed its budgeting procedure and taken steps to ensure that the original factory and laboratory estimates are prepared on as broad a basis as possible and contain no more detail than is essential to ensure the build-up of a realistic total. The Authority agrees with the Committee's view of the importance of taking account of long-term effects, both in staff and further capital expenditure, of current proposals, and will include in any application for sanction of a capital project connected with the development of a new reactor system a rough forecast of expenditure which may be necessary in the foreseeable future as a consequence of the particular capital project for which sanction is requested. The Authority also accepts that the Treasury should be informed of the contingency margin allowed in project estimates for experimental facilities for which it is impossible to give precise detailed specifications at the outset, and the Treasury will also be informed at the next stage of estimating what margin has been retained as a working margin. The Authority also accepts the general intention of the recommendation that it should be standard practice to allow design officers sufficient time to go out to tender for all major components of large civil reactor and plant projects, and fully endorses the Committee's statement that "the future course of the nuclear power programme will be directly affected by the availability or otherwise of the fast reactor in the early 1970's, which means that its value must be established by about 1966". The fast reactor is regarded as an integral part of the nuclear power programme and the Authority will press on with its development as rapidly as possible: it is already receiving, and will continue to receive, full technical support.

On the financial side it must be observed that the balance sheet appended to the report still gives no indication as to the way in which the £92,433,010 of the 1959–60 estimates were expended. The sixth report, like its predecessors, gives no indication whatever of the magnitude of our effort in research on nuclear energy or of the cost of the nuclear power programme, either as a whole or in the development of reactors. Indeed, even less information is available than was to be found in some earlier reports, though it is stated that early in 1959 the Authority decided to limit the growth of man-power on research and development for the next three years to an annual rate of not more than 8 per cent. Within this rate of expansion, recruitment in general has been satisfactory, although difficulty is still experienced in recruiting engineers and scientists of sufficient experience and calibre for higher management posts, and in obtaining scientific and professional staff in particular disciplines in which there is a national shortage. The total staff employed increased from 35,260 on April 1, 1959, to 38,500 on March 31, 1960, industrial employees increasing from 18,217 to 19,572.

On the production side the report records an increase of 40 per cent in the output of fissile material and of 300 per cent in that of electricity, while most of the teething troubles of the full-scale prototype unit for converting uranium nitrate into tetrafluoride, using fluidization techniques, have been overcome, and the plant is operating as a production unit yielding uranium tetrafluoride of good quality at the design throughput. Satisfactory progress is also recorded in the reactor development programme, and stress is laid on the importance of reductions in capital costs if nuclear power is to be competitive not only at base load but also at the lower load factors at which nuclear power stations will have to operate when substantial nuclear capacity has been built. This largely depends on the development of more advanced reactors, and here a large effort has been devoted to the support of the 'magnox' stations, particularly the development of fuel elements to provide good performance with reliability. Progress in the advanced gas-cooled reactor system has been encouraging: the system should be capable of lower capital costs than 'magnox' stations and its prospects are good. Development of the fast reactor proceeded steadily, and the experimental reactor at Dounreay came into operation at low power. Most of the staff working on the high-temperature gas-cooled reactor system were seconded to the *Dragon* project, under the auspices of the Organization for European Economic Co-operation. Other work on reactors included investigations into the design of a steam-cooled heavy-water reactor and its variant, the steam generating heavy-water reactor.

The wide range of the Authority's research activities is displayed in the chapter on general research and development. In nuclear physics, for example, a major group of work is concerned with the behaviour of nucleons when they collide in free space, uncomplicated by the proximity of other nucleons as in nucleon–nuclear reactions. The cyclotron has also been used to investigate the interaction of a high-energy nucleon with a nucleus and the interactions between nucleons and nuclei have also been studied at fairly low energies, using the 5-MV. Van de Graaff generator and newly completed 12-MV. tandem electrostatic accelerator at Harwell. A new particle detector has been developed in which a p–n junction in a semiconductor, such as silicon or germanium, is used as a solid-state ion chamber to produce an electrical impulse when a nuclear particle traverses the junction, and also a large heavily shielded liquid scintillation counter for work on neutron emission in fission. In solid-state physics a fundamental experiment has been carried out using lithium isotopes, and a change of thermal resistance with isotope concentrations was observed in measurements at Capenhurst of the thermal conductivity of single crystals of lithium fluoride containing lithium-6 and lithium-7 in the temperature range 10°–90° K. In radiation chemistry much work has been undertaken in connexion with the problems of radiation change in reactors and in fuel processing plants. For example, work on the γ-radiolysis of methyl acetate has shown how complicated the degradation of a simple ester can be, and work on the radiolysis of trialkyl phosphates showed that, in addition to hydrogen and light hydrocarbons, dialkyl and smaller amounts of mono-alkyl phosphoric acids are produced. The behaviour of the system carbon dioxide/carbon monoxide/graphite under irradiation has been studied to determine the basic parameters that affect the rates of the reactions, and the influence of geometrical factors on the radiation-induced reaction producing carbon mon-

oxide is being studied in sealed tubes. Another investigation was concerned with the nature and properties of radioactive aerosols, and laboratory experiments have been made on the release of iodine in air and carbon dioxide at very low vapour concentrations. Considerable technical work has been undertaken into criticality to back particular design studies as well as a more generalized study.

Work continued on the application of radioisotopes, especially in industry. The method of fluorescence spectroscopy, using radioactive sources, has been applied to measuring very thin surface coatings, and by tracer methods the rate of flow of liquid in closed channels can now be measured with an error of less than one part in 200. Further work has been done on the use of large sources of γ-radiation for sterilization and other purposes, and a pilot-scale plant for irradiating packages of materials with γ-rays has been built at Wantage. A mass spectrometer has been developed at Capenhurst for the analysis of the active species present in gas/solid chemical reactions, and basic studies have been made of the friction and wear behaviour of materials in reactor coolant environments at high temperatures. Considerable progress has been achieved at Aldermaston in the provision of short-duration radiographs of systems opaque to ordinary light and moving at high speed, and two types of mechanical very-high-speed cameras are manufactured at Aldermaston, one, the streak camera recording along a length of film the size of a light source which is varying with time, the other, the framing camera, producing individual pictures at intervals on a strip of film. A third type takes a single picture with a time of exposure of 1×10^{-7} sec., using a Kerr cell shutter.

In the work on controlled thermonuclear reactions, the stored energy supply and the stabilizing magnetic field supply of *Zeta* were both increased by about six times during the year, and experimental elucidation of the physical phenomena in the *Zeta* and *Sceptre* plasmas continued successfully, while work also continued on some other plasma physics problems, and considerable progress was made in solving the formidable technological problems associated with the production and control of currents in the range of 10^6 amp., and in the development of methods of construction to withstand the severe conditions expected in experiments such as the Intermediate Current Stability Experiment. The Authority has reconsidered its earlier decision to move controlled thermonuclear research from Harwell to Winfrith, and has chosen instead a site at Culham, where the laboratories to be erected will form a large autonomous unit within the Authority's Research Group. The Authority's commitments under its long-term uranium contracts are now greater than its immediate requirements, and for some years, mainly due to the slowing down of the nuclear power programme, it will hold larger uranium stocks than it needs. A new Health and Safety Branch, independent of the Groups, was established as from July 1, 1959, to advise on the formulation of health and safety policy and disseminate this policy for application by heads of groups and establishments, apply this policy to the assessment and inspection of reactors and plant, and provide the focal point for conducting external relations in this field. A wide range of health and safety problems investigated during the year included developments in measuring techniques applied to the monitoring of fall-out from nuclear weapon tests, controlled studies of the uptake from fresh water of strontium-90 by fish and of this and other radioisotopes by common aquatic plants, and work on the diffusion and dispersion of gases and particulates.

Information Services have included, besides the Harwell Reactor School, the Calder Operation School, the Isotope School, now at Wantage, and the training programme for Central Electricity Generating Board operating staff, the issue of an illustrated summary of this sixth annual report, together with some additional material to July 1, 1960*.

* Atom 1960: an Illustrated Summary of the Sixth Annual Report from 1st April, 1959, to 31st March, 1960, of the United Kingdom Atomic Energy Authority, with some additional material to 1st July, 1960. Pp. 34. (London: H.M. Stationery Office, 1960.) 2s. 6d. net.

TUBERCULOSIS: RISK TO FAMILY CONTACTS

In developed countries with adequate hospital accommodation, drug treatment of tuberculosis has often freed beds. In less-developed countries with inadequate hospital accommodation, the problem of beds for tuberculous patients remains acute. In India, for example, it is particularly serious, since there are only 23,000 beds for tuberculous patients, against a total number of persons affected that may be put at between 1·5 and 2·5 million. Because of this, a comparative study of domiciliary and sanatorium treatment of tuberculosis was undertaken by the Tuberculosis Chemotherapy Centre, Madras, which was set up in 1956 under the joint auspices of the World Health Organization, the Indian Council of Medical Research, the Madras Government and the Medical Research Council of Great Britain. The purpose of the study was to determine whether drug treatment of tuberculosis in a country like India was as effective in the home as in the sanatorium; or, to put it differently, whether domiciliary treatment did away with the need to send a fair number of tuberculosis patients to hospital (*World Health Org. Chron.*, 14, No. 7; July 1960).

A group of 193 patients were selected, most of them from the poorest classes of Madras City. They had to be more than twelve years old, to have had no previous drug treatment, and to have a positive sputum. Out of these 193 patients, 96 were treated at home, 97 in the sanatorium. The period of comparison lasted a year, and the results of the study indicated that domiciliary treatment seemed to give as good results as sanatorium treatment.

There remains the important point whether the risk of infection to the family is not greater when the patient is treated at home. A fresh study was carried out under World Health Organization auspices on the same group of patients to determine the overall prevalence of cases of tuberculosis among family contacts when the diagnosis of tuberculosis was established in the family member included in the comparative study (the index case), and the number of fresh clinical and primary cases occurring among

family contacts during the first year of his treatment. Contacts include all the other members of the family, but the inquiry was limited to 'close' family contacts, that is, those who had been living with the index case for at least three months before diagnosis. In fact, 96·7 per cent of the 693 close family contacts had been living with the index case for at least a year.

Examinations were carried out in 693 contacts of the 193 patients treated at home or in the sanatorium; of these, 347 were men and 346 women. The survey of the prevalence of tuberculosis when the index case started treatment was based on 672 contacts. Active tuberculosis was found in 46; in another 2, activity was doubtful; and in 11, tuberculosis was inactive.

Of still more interest was the inquiry into fresh cases of tuberculosis appearing in close family contacts of patients treated either at home or in the sanatorium during the first year of treatment. There were 257 contacts of the 75 patients treated at home, and 275 contacts of the 73 patients in the sanatorium. The two groups were alike in the proportion of men to women, in the kind of home they lived in and in the results of the initial examination; and they were followed up in the same way during the year of the inquiry. During this year, 26 active cases of tuberculosis were discovered in the two groups of contacts; 9 (3·5 per cent) in the group of contacts of patients treated at home, and 17 (6·2 per cent) in the group of contacts of patients treated in the sanatorium.

Of these 26 cases, 15 were less than five years old and 21 less than two years old. The most serious cases all belonged to the group whose index cases were treated in the sanatorium.

Even if encouraging conclusions can be drawn from this study, domiciliary treatment of the open tuberculous patients should be considered an emergency measure only, to be taken when institutional treatment for 3–6 months is impossible because of shortage of beds. Every effort should be made not to send patients home until their sputum has become negative for tubercle bacilli, at least on microscopical examination.

A final conclusion is that the frequency and seriousness of tuberculosis lesions in young contacts are a sufficient justification for systematic prophylactic treatment of children whenever a sputum-positive patient is newly diagnosed in their household. This treatment should be started immediately and carried out for a minimum period of six months.

NOISE IN FACTORIES AND ITS CONTROL

NOISE is always associated with the application of power, and the trend towards the use of more powerful machines in industry is making the problem of noise in factories increasingly serious. A survey "Noise in Factories", by A. G. Aldersey-Williams, which has recently been published for the Department of Scientific and Industrial Research (Building Research Station) in the series "Factory Building Studies" (No. 6. Pp. iv+26. London: H.M. Stationery Office, 1960. 3*s*. 6*d*. net), emphasizes that the noise factor should be considered at the earliest stages in the planning of a factory. Choice of the manufacturing method, which largely determines the noise-level and its effect on the occupants of the factory and residents in the area, is the responsibility of the management. Noise at source can be reduced by machine manufacturers in the design of their machines, but where this is not possible, factory engineers can minimize the effect by taking precautions in the installation of the machines, and the building designer can reduce annoyance by siting noisy equipment away from other buildings and by the use of enclosures and sound-absorbing roof linings.

The 26-page booklet consists of two parts. Part 1 deals with the properties of sound and explains the terms used, the sources of noise in factories, and the effects of noise. It is pointed out that the most intense noise in factories is generally caused by machine tools and by operations involved in making and handling the product, and it is only when the process is a quiet one that the noise from service equipment, such as fans, pumps and compressors, may be the more intense. Excessive noise will influence the welfare, safety and, indirectly, the efficiency of the occupants of the factory. As the level of noise increases, its effect on people is first annoyance, then interference with communication and, finally, damage to hearing. In addition, since noise is associated with vibration, the performance of delicate equipment in the factory may be upset, and if the noise is transmitted through the factory structure or through the ground to the outside of the factory, it may also cause discomfort.

In Part 2, methods for the reduction of noise and their effectiveness are discussed. The radiation of noise, resonance and damping, and vibration isolation are dealt with first, then noise reduction and lay-out, enclosures to reduce noise, sound-absorbing materials, partial enclosures and screens, and finally ear protection. The most effective way of controlling noise once it has been generated and radiated is to contain it within an enclosure, a reduction of about 50 db. being readily provided by an ordinary building enclosure; but the efficiency of an enclosure depends on its completeness and uniformity, and direct air leaks through a hole or through porous material reduce the efficiency considerably. The build-up of reverberant sound within an enclosure can be controlled by the use of sound-absorbing materials to reduce the amount of sound reflected. The booklet gives a list of absorption coefficients of common sound-absorbing materials and contains illustrations of various sound-absorbing arrangements in factories. For individual ear protection, where operators of noisy machines are exposed to high levels of noise, two forms of commercially available 'ear defenders' are ear plugs and ear muffs. Ear plugs are inexpensive, small and inconspicuous, but may be uncomfortable when first worn. Dry cotton wool is not an effective ear plug. Ear muffs fit over the ears, and though heavier and more expensive than ear plugs, they give greater reduction of noise. In the latest types the seal around the ear is made by a plastic cushion partly filled with liquid, and the muff is very comfortable to wear even for long periods of time.

S. WEINTROUB

PENETRATION OF CHARGED PARTICLES IN MATTER

DURING September 15–18, 1958, an informal conference was held at Gatlinburg, Tennessee, to discuss the penetration of charged particles in matter. Penetration of Charged Particles in Matter: Proceedings of an Informal Conference, Gatlinburg, Tennessee, September 15–18, 1958. Edited by A. Vehling. (Nuclear Science Series, Report No. 29. Publication No. 752.) Pp. x+174. (Washington, D.C.: National Academy of Sciences—National Research Council, 1960.) 2 dollars.) The conference, which was attended by about fifty scientists from Canada, Europe, Asia and the United States of America, was organized by the Sub-committee on Penetration of Charged Particles in Matter of the National Academy of Sciences—National Research Council and sponsored by the United States Atomic Energy Commission, National Science Foundation, and the Air Force Office of Scientific Research.

About twenty-five talks were given and the proceedings of the conference, edited by E. A. Vehling of the University of Washington, have now been published. Topics ranging from the reliability of experimental data to new approaches in the theoretical description of energy-loss mechanisms were discussed. The papers are presented under five headings: stopping power and range, recent developments in the theory of stopping power, charge-changing collisions, atomic and molecular scattering, ionization in gases by high-energy particles, and microscopic and macroscopic energy-loss distributions.

Prof. S. K. Allison, who introduced the papers on charge-changing collisions, discusses measurements on the formation of negative lithium ions, and C. Y. Fan explains briefly the spectroscopic study of electron-capture processes. U. Fano summarizes the various theoretical reviews given in the final section of the proceedings dealing with energy-loss distributions and adds an appendix in which he comments on 'collective' effects in atoms and in extended media. J. B. Hasted, of University College, London, the only representative from the United Kingdom, reports on coincidence methods of studying inelastic ionic collisions.

The articles have been prepared either by the speakers or by the chairmen of the various sessions in collaboration with the speakers. In some instances the reports include the results of the subsequent discussions. In a few cases the original reports have been shortened or reduced to abstract form because of publication of the full report elsewhere. References are given.

EQUATORIAL SPREAD-*F* AND *F*-LAYER HEIGHTS

By Dr. A. J. LYON and Dr. N. J. SKINNER
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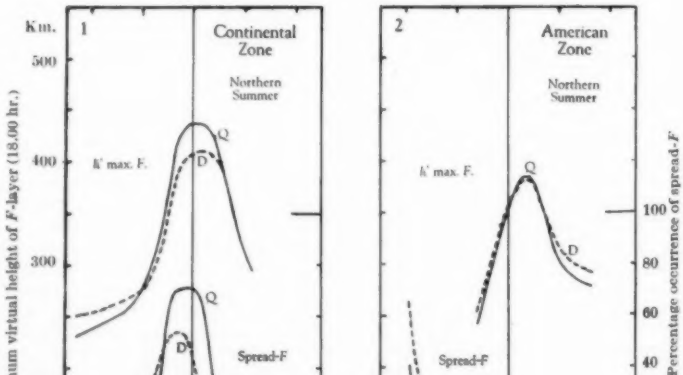
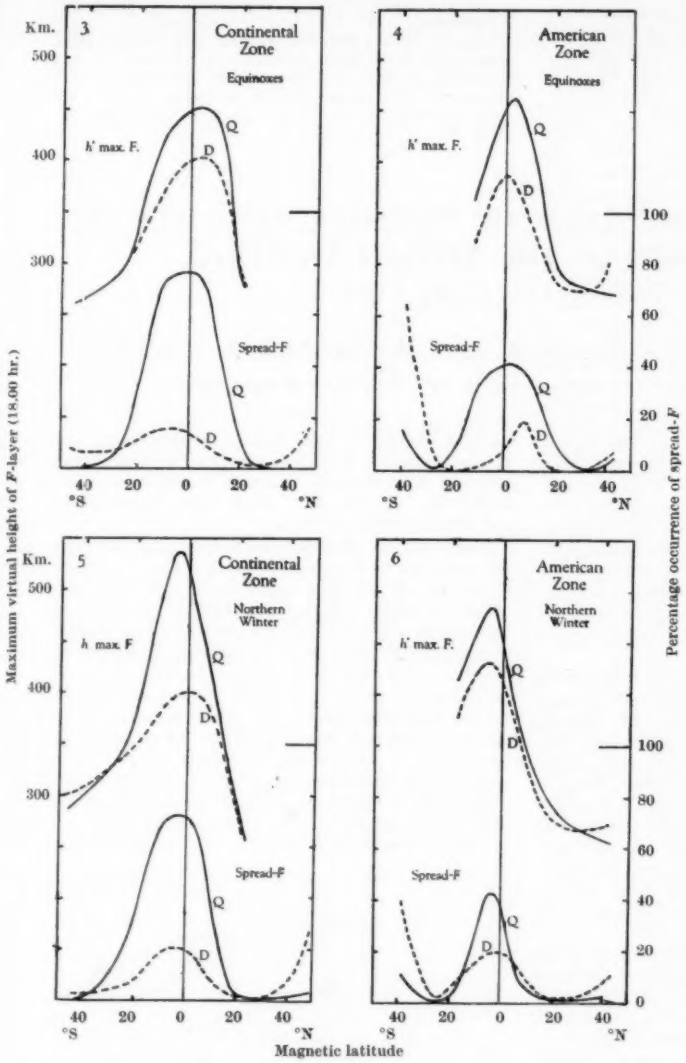
AND
Prof. R. W. WRIGHT
University College of Ghana, Legon, Ghana

WE recently reported[1] on the surprising inverse correlation observed near the magnetic equator between the occurrence of spread-*F* echoes and magnetic disturbance, in contrast to the direct correlation observed at temperate latitudes. The evidence then presented related to the exceptionally disturbed month of September 1957, and was derived from observations at only a few ionospheric stations. We have now extended our analysis to cover a twelve-month period of the International Geophysical Year (November 1957–October 1958), and have used observations from about sixty stations distributed over a wide range of magnetic latitude. In addition we have made a parallel study of the rapid rise in the height of the equatorial *F*-layer which occurs just after local sunset (from about 300 km. to more than 400 km. in 1–2 hr.). It



Figs. 1 and 2



Figs. 3–6. Variations of $h'_{max.}$ F, the maximum value of $h'F$ in the six hours after local sunset, and of the percentage occurrence of spread-F, both plotted against magnetic latitude, for magnetically quiet (Q) and magnetically disturbed (D) conditions

was noted many years ago[2,3] that this rise occurs just prior to the development of the spread-F condition.

The twelve months under review were divided into three 'seasons', and the stations were divided into two zones, the American zone and the 'Continental zone' comprising Europe, Africa, and Asia. The mean percentage frequency of the occurrence of spread-F at night, and the mean maximum virtual height ($h'_{max.}$ F) reached by the F-layer in the early part of the night, were computed both for magnetically quiet and for magnetically disturbed conditions for all the stations. The spread-F index was derived mainly from published tables of f_0F_2, but was checked whenever possible by reference to the ionograms. The results of this analysis are summarized in Figs. 1–6. The upper curves refer to heights and the lower ones to the spread-F index in each case, and both parameters are plotted against magnetic latitude.

A number of conclusions may be drawn from these graphs.

(1) The equatorial belt, within which spread-F is a common occurrence under magnetically quiet conditions, extends from roughly 20° north to 20° south of the magnetic equator. The smaller incidence in the American zone is at least partly due to different conventions in scaling the data. There is probably little if any difference in the general incidence of spread-F between the hemispheres. Only in one case (northern summer, American zone, Fig. 2) is the belt substantially narrower.

(2) Within this belt there is in general a sharp diminution of spread-F during magnetic disturbance. (Again only American summer is exceptional.)

(3) The change-over to a direct correlation between spread-F and magnetic activity generally occurs at about 30° N. or 30° S. magnetic latitude.

(4) In the American zone there is a small seasonal movement (about $\pm$ 5°) of the maximum of the spread-F belt, but no corresponding movement has been detected in the other region.

(5) Comparison of the upper and lower curves in Figs. 1–6 shows that there is a remarkably close coincidence between the spread-F belt and the belt of steep post-sunset rise in $h'F$. The widths of the belts and the positions of the maxima agree very well; in particular, in the American zone the belt of rising $h'F$ follows exactly the seasonal movement of the spread-F belt. Moreover, the reduced spread-F incidence during magnetic disturbance corresponds to reduced rise of $h'F$ in every case. Perhaps most convincing of all, in the one exceptional case where there is no reduction in spread-F during magnetic disturbance (Fig. 2), there is also no reduction in the rise of $h'F$; and indeed in this case both the rise in $h'F$ and the spread-F incidence are the smallest.

The remarkable correlation between the occurrence of spread-F and the prior rise of height of the layer might be accounted for in terms of Martyn's theory[4], which ascribes the irregularities producing spread-F to upward vertical drift of ionization. Alternatively, it might be considered to support the theory of Dessler[5] that spread-F arises from hydromagnetic waves of extra-terrestrial origin propagated downwards and "channelled by refraction into the 400 km. level". The evidence of Figs. 1–6 might well suggest that a height of about 400 km. is critical for the formation of spread-F. However, neither theory appears to account satisfactorily for the fact that equatorial

spread-*F* usually continues throughout the night, even although after about 20 hr. the height of the layer decreases and for much of the night is below 300 km.

The results summarized above will shortly be published in greater detail elsewhere.

[1] Lyon, A. J., Skinner, N. J., and Wright, R. W., *Nature*, **181**, 1724 (1958).
[2] Booker, H. G., and Wells, H. W., *Terr. Mag.*, **43**, 249 (1938).
[3] Osborne, B. W., *J. Atmos. Terr. Phys.*, **2**, 66 (1951).
[4] Martyn, D. F., *Proc. Inst. Rad. Eng.*, **47**, 147 (1959).
[5] Dessler, A. J., *J. Geophys. Res.*, **63**, 507 (1958).

A NEW LIMIT TO THE GALACTIC MAGNETIC FIELD SET BY MEASUREMENTS OF THE ZEEMAN SPLITTING OF THE HYDROGEN LINE

By Dr. R. D. DAVIES, C. H. SLATER, W. L. H. SHUTER and P. A. T. WILD

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THE existence of a magnetic field in the Milky Way system has been inferred from the regularity in direction of polarization of the light from distant stars, from the isotropy of high-energy cosmic rays and the presence of galactic radio-frequency emission attributed to the synchrotron mechanism. However, none of these observations gives a direct measure of the magnitude of the galactic magnetic field; various estimates of the magnetic field in the galactic disk based on these data give values in the range $0{\cdot}5 \times 10^{-6}$ oersted to 3×10^{-6} oersted.

The Zeeman splitting of the line radiation from interstellar neutral hydrogen can be used as a technique for detecting weak interstellar fields. The line-of-sight component of the magnetic field gives rise to a splitting of the radiation into left- and right-hand circularly polarized components separated by 2·8 mc./s. per oersted. The effect is most readily measurable in the narrow deep absorption features in the spectra of the intense radio sources. A previous attempt to detect the field in this way gave an upper limit of 5×10^{-6} oersted[1]. The present article describes further experiments which set a new limit to this interstellar magnetic field.

The three deep lines in the Cassiopeia-*A* absorption spectrum were studied. One is caused by a cloud in the Orion arm and two by clouds in the Perseus arm. The narrow feature investigated in the Taurus-*A* spectrum is in the Orion arm and that in the Sagittarius-*A* spectrum is in the 3 kiloparsecs expanding arm. The positions of all the five clouds studied are indicated schematically in Fig. 1. The experiment was conducted in two parts; the Orion arm cloud and the 'near' Perseus arm cloud of the Cassiopeia-*A* spectrum were measured in the period March 6–22, 1960, while the three other clouds were investigated during May 26–June 7, 1960.

The experimental technique consisted of controlling the 250-ft. radio telescope to follow the required radio source and switching the receiver to accept left-hand and then right-hand circular polarization once every 24 sec. This polarization switching was effected by rotating a quarter-wave dielectric plate from one plane to the other of the square wave-guide section which illuminated the paraboloid. The receiver incorporated a phase-sensitive detector and would respond to any Zeeman splitting since this would produce a phase-sensitive component with a 24-sec. period. The half-power band-width used was 7 kc./s. in all measurements except those on the narrow feature in the Taurus-*A* spectrum, where it was 4 kc./s. A given absorption feature was then scanned in frequency using a variable second local oscillator. 60–100 such scans were taken on eac of the five absorption lines.

Each of the absorption profiles was analysed for the presence of a magnetic field in the following way. About 40 of the best scans were added together to obtain a mean curve. If polarization were present this curve would have the shape of the differential of the absorption profile and for any given profile the amplitude of this expected curve would be directly proportional to the strength of the magnetic field. As an example, the mean curve and the absorption profile observed in the Orion arm cloud in the Cassiopeia-*A* spectrum are shown in Fig. 2. Each mean curve was then fitted by an expected curve the amplitude of which gave the least-squares deviation, and the magnetic field corresponding to this curve is given in column five of Table 1 together with the

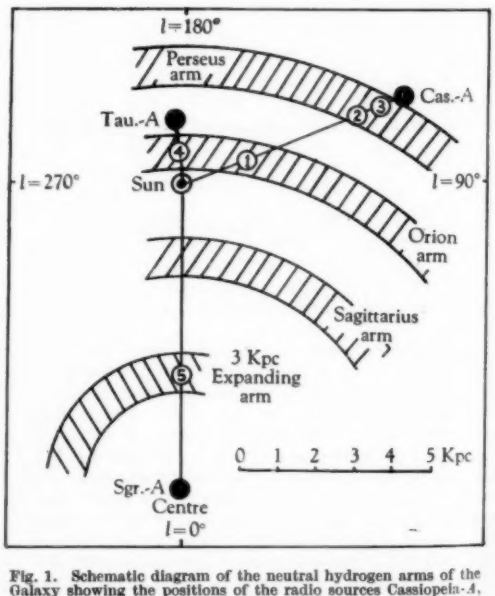

Fig. 1. Schematic diagram of the neutral hydrogen arms of the Galaxy showing the positions of the radio sources Cassiopeia-*A*, Taurus-*A* and Sagittarius-*A* (filled circles), and the absorbing clouds (open circles) studied in this investigation

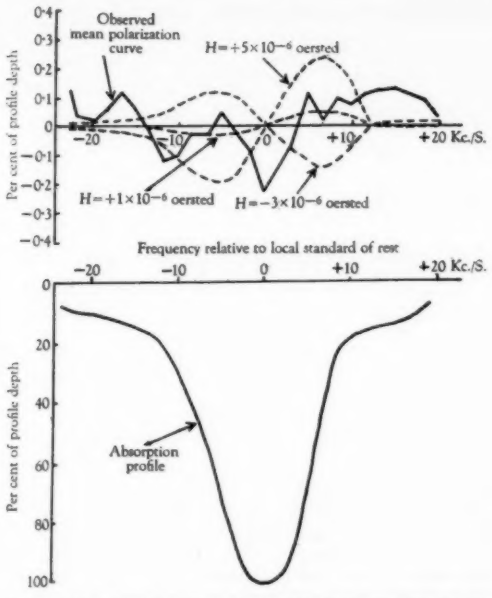

Fig. 2. Limits of the magnetic field in the Orion arm cloud in the direction of Cassiopeia-*A*. The full-line plot is the mean of the observed scans and the dotted curves are those for the best fitting magnetic field and the fields a standard deviation different. The plot underneath shows the shape of the Orion arm absorption profile

estimated standard deviation. The magnetic field is tabulated as positive when directed away from the observer.

These results give no positive evidence for a magnetic field in any of the clouds studied. The line-of-sight component of the magnetic field in each of the three clouds in the direction of Cassiopeia-*A* is less than 1×10^{-5} oersted, and indeed for the case of the Orion arm cloud it is less than $0{\cdot}5 \times 10^{-5}$ oersted.

Table 1. Limits of the Magnetic Field determined from Absorption Features in Three Intense Radio Sources

	Source	Velocity displacement of absorption feature (km./sec.)	Galactic longitude (new co-ordinates)	Magnetic field (units of 10^{-5} oersted)
1.	Cassiopeia-*A* (23*N*5*A*)	− 1 (Orion arm)	112°	+ 1 ± 4
2.	Cassiopeia-*A* (23*N*5*A*)	− 38 (Perseus arm)	112°	+ 1 ± 7
3.	Cassiopeia-*A* (23*N*5*A*)	− 48 (Perseus arm)	112°	− 3 ± 7
4.	Taurus-*A* (5*N*2*A*)	+ 10 (Orion arm ?)	185°	+ 10 ± 10
5.	Sagittarius-*A* (17*S*2*A*)	− 53 (Expanding arm)	0°	+ 14 ± 40

If the magnetic field configuration follows the spiral pattern of the Galaxy the line-of-sight to Cassiopeia-*A* would make an angle of about 30° to the direction of the field. Accordingly the magnitude of the actual field has limits only 15 per cent greater than those given for the Cassiopeia-*A* features shown in Table 1.

The measurements on the Taurus-*A* cloud gave a higher limit to the magnetic field because it is a weaker absorption feature. Nevertheless they show that the radial field of the Galaxy near the Sun is less than 2×10^{-5} oersted. The cloud studied in the Sagittarius-*A* spectrum shows a radial component of magnetic field less than 5×10^{-5} oersted. It lies in the 3 kiloparsecs expanding arm where anomalous conditions occur[2] and the magnetic field may be substantially higher than farther out in the galactic disk near the Sun. Here the neutral hydrogen gas is expanding outwards at 50 km./sec. having left regions nearer the centre where the expansion velocity is 200 km./sec.

The upper limit of the magnetic field in the disk of the Galaxy set by this experiment is smaller by a significant factor than that demanded by some theories. The theory of Biermann[3], which explains the synchrotron radio emission from the Galaxy in terms of electrons derived from cosmic rays, requires fields of $2\text{–}3 \times 10^{-5}$ oersted in the galactic disk. The model of the Galaxy proposed by Elvius and Herlofson[4] postulates a magnetic field of 2×10^{-5} oersted. Attempts to understand the polarization of starlight[5] have often required fields of greater than 1×10^{-5} oersted. Such theories may have to be reconsidered in view of the present results.

We wish to thank Prof. A. C. B. Lovell, director of the Laboratories, for making available the facilities for this research. The help gained from discussion with Prof. R. Hanbury Brown is also gratefully acknowledged. The programme of research was supported by a grant from the Department of Scientific and Industrial Research.

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COMPARISON OF THE CHEMICAL COMPOSITION AND MAGNETIC PROPERTIES OF TEKTITES AND GLASSES FORMED BY FUSION OF TERRESTRIAL ROCKS

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IT has been suggested by some investigators[1] that tektites are of terrestrial origin and hence were formed in an atmosphere of composition similar to that surrounding the Earth to-day. In particular, Hawkins[2] has pursued the hypothesis that tektites may be a special form of fulgurite. In order to shed more light on this problem an attempt has been made to determine the changes in chemical composition that silicate rocks would undergo when heated to 2,000–3,000° C., in air in a solar furnace. The fused materials were analysed chemically and magnetically before and after fusion.

Table 1. Chemical Composition of Rock Melts before and after Heating*

	Sand, Big Stone Gap, Va. 3104–2, 3		Bentonite, Phoenix, Ariz. 3104–6, 7		Basalt glass, Hawaii 67–3, 4617–4		Obsidian, Iceland 3024–1 4617–1		Rhyolite, Thomas Mts., Utah, 4617–3A, 3B		Rhyolite, New Mexico, 2–2 3104–4, 5	
SiO_2	89·3	87·0	68·7	68·2	51·8	51·8	73·8	74·7	77·3	76·6	76·7	76·7
Al_2O_3	4·5	6·8	18·6	19·0	15·0	15·0	13·7	14·0	12·6	13·2	13·0	13·1
Fe_2O_3	2·5	1·0	1·3	0·5	0·9	2·4	0·7	0·4	0·9	0·3	0·3	0·3
FeO	1·4	2·5	0·00	0·72	10·3	8·8	1·7	1·9	0·05	0·68	0·79	0·68
MgO	0·39	0·59	6·9	7·1	7·4	7·4	0·12	0·13	0·08	1·0	0·04	0·05
CaO	0·77	1·0	1·2	1·1	11·8	11·7	1·0	1·0	0·75	1·5	0·58	0·51
Na_2O	0·21	0·20	2·9	2·8	2·4	2·4	4·8	4·3	3·4	2·9	4·0	4·0
K_2O	1·1	0·92	0·49	0·53	0·56	0·55	4·0	3·5	5·1	4·7	4·6	4·6
$Na_2O + K_2O$	1·31	1·12	3·39	3·33	2·96	2·95	8·8	7·8	8·5	7·6	8·6	8·6
Fe^{2+}/Fe^{3+}	1·63	0·36	0·91	0·62	0·08	0·24	0·37	0·19	16·2	0·40	0·34	0·40
Magnetic susceptibility χ (10^{-6} e.m.u./gm. units)	41	32	1·33	1·23	17·1	16·0	4·75	3·31	0·2	1·1	11·6	1·41
Magnetization, σ (10^{-6} e.m.u./gm. units)	2,640	660	1·20	0	0	0	50·6	0	19·6	0	107	0
Heating time	45 min.		3 min.		5 min.		15–20 min.		15–20 min.		5 min.	

* Analyses performed by Rapid Rock Analysis Group, U.S. Geological Survey.

The rock samples were heated by placing them at the focal spot of the solar furnace at the U.S. National Bureau of Standards. This unit consists of an 8-ft. square mirror controlled photoelectrically by a heliostat and adjusted to reflect the Sun's light into a 60-in. diameter parabolic mirror of 24-in. focal length. A relatively large specimen is fastened in a holder that can be moved independently around three mutually perpendicular azimuths by means of individual electric motor drives. The operator can view the sample through a small hole in the centre of the parabolic mirror. The hot focus can thus be moved to different parts of the specimen by the motor drives on the sample holder in order to melt an area larger than the focal area. The construction of the furnace makes it necessary to have the sample mounted vertically, and any molten material produced tends to drop off after a relatively short time. This limits the time of heating for those rocks the melts of which are very fluid, such as basalt. In the case of the bentonite and basalt glass, the material dropped off after a few minutes of heating at temperatures estimated to be more than 2,500° C. The more siliceous melts, on the other hand, were far more viscous, and the molten area could be kept hot for periods of 1/2 hr. or more before they dropped off.

The temperature measurements were crude estimates, at best. The melts were far from black bodies, and tended to reflect the Sun into the optical pyrometer, which tended to make the temperature readings high. The value of $2,500 \pm 300°$ C. is thus a rough estimate corrected for reflexion.

Total chemical analyses by the method of Shapiro and Brannock[3] were made on all the unheated and fused specimens. As magnetic measurements have been used to show the state and quantity of iron in glasses (see Senftle and Thorpe[4]), the magnetic susceptibility and saturation magnetization were also measured on all samples before and after heating. The results listed in Table 1 have been reduced to a water-free basis.

In tektites the monovalent alkali oxides (K_2O, Na_2O) are generally lower than the divalent oxides (FeO, MgO, and CaO). It was expected, therefore, that due to loss of volatiles, the chemical composition of the fused rocks might approach the average composition of some of the tektites as shown in Table 2. The loss of silica and alkalis and the concentration of alumina are apparent in most of the samples. However, the changes are small, and one can conclude that much higher temperatures and/or longer periods of heating would be necessary to change the composition of even an obsidian to that of an indochinite, two materials the silica and alumina composition of which are fairly close even before heating.

Another interesting observation is that the ferric–ferrous iron ratio in the fused samples tends to approach the average value of 0·4. The iron in the basalt and rhyolite glasses oxidized whereas that in the obsidian and other more oxidized materials was reduced. The reduction of ferric to ferrous iron in air begins at some temperature between 1,300° C. and 1,400° C. primarily due to the decomposition of Fe_2O_3. Abou-el-azm[5] has examined the change in composition of many silicate glasses with temperature, and has shown that the ferrous iron increases rapidly above 1,400° C. By extrapolation of his results it can be shown that in the region of 1,700° C. the conversion of Fe^{3+} to Fe^{2+} reaches a limiting value. He has also found that if the ferric–ferrous ratio is low (high ferrous iron) initially, part of the ferrous iron tends to be oxidized due to contact of the glass with the air at the surface of the melt, or by oxygen contributed by the other constituents. His work indicates that the melt approaches an equilibrium between Fe^{3+} and Fe^{2+} depending on the available oxygen and the temperature of the melt. Thus, it can be expected that as the temperature is raised above 1,700° C., the ferric–ferrous ratio of fused rock will approach a limiting value for a given oxidizing atmosphere.

In the experimental work reported here the fused rock glass was in contact with 1/5 atmosphere of oxygen at approximately 2,500° C. At this oxygen pressure and high temperature the ferric–ferrous iron ratio appears to approach an equilibrium value of about 0·4. In comparison, the same ratio for tektites is somewhat smaller as shown in Table 2. This difference in the ferric–ferrous ratio between fused rocks and tektites suggests that the tektites were probably heated in a gas phase the partial pressure of oxygen of which was less than 1/5 atmosphere.

If the last heating of the tektites occurred as they passed through the atmosphere, it is possible that the major portion of the heating occurred in the upper atmosphere at oxygen pressures many orders of

Table 2. Average Composition of Tektites (Computed from Data given by Barnes, ref. 6)

	Philippine tektites	Texas tektites	Moldavites	Indochinites	Billitonite and assoc. tektites (not Java)	Australites	Java tektites
SiO_2	71·21	75·64	79·60	73·14	70·50	73·33	73·73
Al_2O_3	12·57	14·59	11·02	12·48	12·53	12·75	11·33
Fe_2O_3	1·47	0·41	0·15	0·19	0·74	0·50	0·83
FeO	4·19	4·00	2·24	4·98	5·27	4·25	4·46
MgO	2·90	1·28	1·30	2·00	3·07	1·98	2·39
CaO	3·19	0·05	1·92	2·51	3·14	3·01	2·49
Na_2O	1·52	1·36	0·51	1·45	1·75	1·25	1·15
K_2O	1·93	1·85	3·00	2·40	2·28	2·05	2·32
H_2O^+	0·37	0·05	0·07	0·28	0·45	0·19	0·25
H_2O^-	—		0·04	0·10	0·09	0·09	0·06
TiO_2	0·89	0·81	0·80	0·94	0·85	0·67	0·87
MnO	0·11	0·01	0·11	0·13	0·16	0·16	0·11
	100·35	100·05	101·39	100·60	100·83	100·23	99·99
Fe^{3+}/Fe^{2+}	0·31	0·09	0·06	0·03	0·13	0·11	0·17
Average magnetic susceptibility χ (10^{-6} e.m.u./gm. units)*	$7·0_4$	$5·2_2$	$2·6_5$	$6·3_3$	$7·5_0$	$6·1_6$	$7·3_0$

* See Senftle, F., and Thorpe, A. (ref. 4).

magnitude less than at the surface—perhaps as low as 10^{-4} to 10^{-6} atmosphere. As the air density increased, the objects were slowed down and the heat produced was lost more efficiently. This is in accordance with the observation that stony meteorites that are heated sufficiently in their passage through the upper atmosphere to form a fusion crust are cool enough to handle by the time they strike the Earth.

The saturation magnetization, σ, of the molten rocks is similar to that reported for tektites. The data in Table 1 show that, after melting, the magnetization dropped to zero (with the exception of the sand specimen from Big Stone Gap, Virginia) in accordance with similar measurements on tektites reported by Senftle and Thorpe[4]. Zero magnetization indicates complete solution of the iron and one therefore concludes that complete solution of the iron has taken place in these melts within the heating time. The above authors have previously shown evidence that the minimum heating time necessary to dissolve particulate iron oxide is probably of the order of 1 min. for temperatures of the order of 2,000° C. and maybe slightly less for higher temperatures. For the experimental temperatures and chemical composition, the heating time shown here can be considered ample to produce tektite-like glass. The heating period of tektites is probably greater than one minute, but not necessarily larger than fifteen minutes, except perhaps for specimens containing a very high silica content, for example, Libyan Desert glass (this glass is not considered to be a true tektite by some investigators).

The change in the value of the magnetic susceptibility is not considered too important from the point of view of the formation of tektites. Its magnitude simply reflects the total iron content, and the observed changes can be explained by the solution of the iron in the glass. Thus, the high susceptibility for the sandstone is due to incomplete solution of the iron in the glass, whereas the high value for basalt glass is due to the high iron content. The rest of the rocks contain less iron than most tektites, and hence their corresponding magnetic susceptibilities are lower than those of tektites.

Table 3 shows the results of the magnetic measurements on the unheated and fused rock in which tektites have been found. The values of the magnetic susceptibility and saturation magnetization are not too unlike that for tektites in general, but the results show that the magnitude of the susceptibility is quite different from that of the tektites found in the area. It indicates that the moldavite contains less iron than the enclosing sand, whereas bediasites contain more iron than the local rock. One cannot help but conclude that tektites are not formed from the local rock in which they are found, for example, by local surface heating or effects of lightning.

In summary, the chemical and magnetic measurements of several types of rocks have been made before and after fusing at 2,500° C. in air at atmospheric pressure. The changes in composition indicate that tektites were either (*a*) melted at temperatures in excess of 2,500° C., or (*b*) heated at this temperature for periods in excess of 20 min. Thus, the small change noted in the composition suggests that the observed composition of tektites probably reflects the composition of the material from which they came. The larger ferric–ferrous ratio of the fused rocks compared to that of tektites suggests that the tektites were melted in an oxygen atmosphere the pressure of which was less than that on the surface of the Earth. The changes observed in the magnetic properties indicate that a heating period of 15–20 min. at 2,500° C. is sufficient to produce magnetic properties similar to those of tektites, but does not preclude the possibility of longer periods of heating. Comparison of the magnetic susceptibility of tektites and the melted rock from the same location show that tektites could not be formed from the rocks in which

Table 3. Comparison of the Magnetic Properties of Tektites and the Glass made from the Enclosing Rock Formation

Sample	Magnetic susceptibility χ (e.m.u./gm.)	Saturation magnetization (e.m.u./gm.)
Sand from Nechov, Bohemia*	$3·35 \times 10^{-6}$	$31·5 \times 10^{-4}$
Glass made from sand	$6·45 \times 10^{-6}$	0
Moldavite from the same site*	$2·04 \times 10^{-6}$	0
Sandstone from Wellborn sandstone of the Jackson group, Texas†	$2·46 \times 10^{-6}$	$1·2 \times 10^{-4}$
Glass made from sand	$2·41 \times 10^{-6}$	0
Bediasites from Texas	$4·2–5·4 \times 10^{-6}$	0

* Specimens collected and contributed by A. J. Cohen, Mellon Institute, Pittsburgh, Pa.

† Specimen collected and contributed by G. S. Hawkins, Boston University Observatory, Boston, Mass.

they are found. The above data suggest that tektites were not formed by heating of surface material *in situ* or by lightning.

We are indebted to Dr. Van Valkenburg of the U.S. National Bureau of Standards for use of the solar furnace. We also thank our colleagues who contributed specimens or helped us by their critical discussions.

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ZONE ELECTROPHORESIS OF ANTHOCYANINS

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THE molecule of anthocyanins has been considered ionic since the classical studies of Willstätter[1]. Migration of these pigments in an electric field should, therefore, be expected. Recently, Schmidt and Schönleben[2] and Wyler and Dreiding[3] observed that the red beet pigment, the anthocyanic nature of which is still in doubt, does show electrophoretic migration.

In this article it is reported that the typical anthocyanins of sour cherries, strawberries, plums and roses, when placed within an electric field applied across filter paper (or cellulose powder), move to the anode or the cathode, depending on the *p*H of the electrolyte solution. The isoelectric points of the two anthocyanins of the tart cherry, *Prunus cerasus* L., var. Montmorency, are also given, along with the observation that the isoelectric points of these anthocyanins seem to coincide with the *p*H at which the pigments display minimum colour.

The Montmorency cherry pigments were in a 70 per cent ethanol extract saved from a parallel experiment on the pectins of this fruit. This extract was stored at 0° C. and aliquots were concentrated at 40° C. in a vacuum, rotating evaporator. The strawberry anthocyanins were extracted with *n*-butanol, and those of the dried rose petals or plum skins with methanol. The extracts were shaken with enough petroleum ether, or ether and petroleum ether, to precipitate the pigments in a small quantity of 1 per cent aqueous hydrochloric acid, and this concentrated aqueous solution of pigment was subjected to paper electrophoresis.

The concentrates of the anthocyanins of various origins were streaked on strips of a Spinco model *R* paper electrophoresis apparatus. A variety of electrolytes such as phosphoric acid, acetic acid, formic acid, or their sodium salts, in concentrations of 0·1 or 0·01 *M*, were found suitable for the electrophoretic separation of the pigments. After the application of a voltage gradient of 7–8 V.cm.$^{-1}$ for 5–10 hr., the pigments generally moved toward the cathode, if the *p*H of the electrolyte was below 6, and toward the anode if the *p*H was above 7. To render the pigmented zones more visible after runs close to the isoelectric point or the alkaline side of it, the strips were exposed to hydrochloric acid fumes. Fig. 1 is a photograph of the strips after electrophoresis of the cherry anthocyanins at various *p*H.

In order to obtain larger quantities of purified cherry anthocyanins for further study, the pigments were separated by means of a Reco model *E*-800-2 flat electrophoresis apparatus. A 5-mm. thick layer of Whatman standard cellulose powder, suspended in 1 *M* acetic acid, was applied on the plate of the apparatus and the pigment concentrate was streaked at three or four different places across the field. With a voltage gradient of 10–15 V.cm.$^{-1}$, satisfactory separation of the two cherry anthocyanins was achieved after 8 hr. The coloured zones were removed, eluted with methanol, and the eluate was concentrated in the vacuum evaporator at room temperature. The electrophoretically isolated pigments showed the same mobilities on the strip electrophoresis apparatus as those displayed when

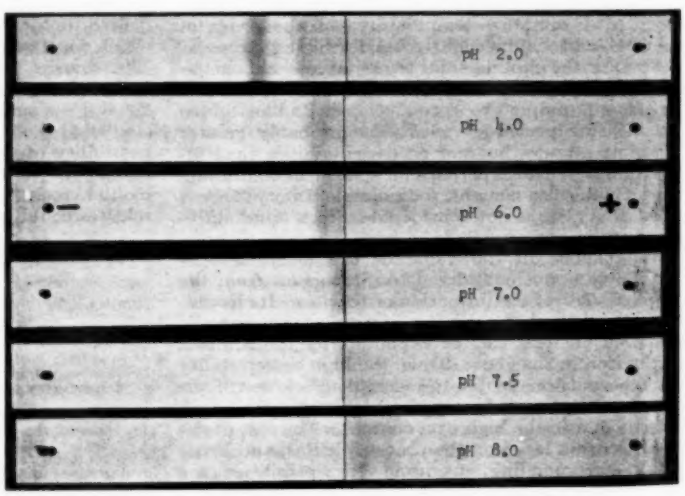


Fig. 1. The anthocyanins of *Prunus cerasus* L. var. Montmorency after paper electrophoresis in a Spinco apparatus. Electrolyte: 0·03 *M* ortho-phosphoric acid adjusted to various *p*H's with sodium hydroxide. Voltage gradient: 7 V.cm.$^{-1}$. Duration: 5 hr. Room temperature

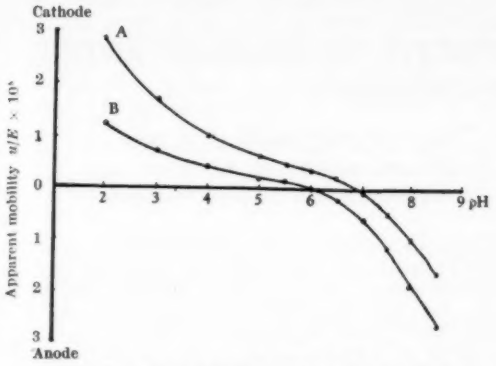


Fig. 2. Apparent electrophoretic mobilities (in cm. per sec. per voltage gradient of 1 V.cm.$^{-1}$) of the Montmorency cherry anthocyanins as functions of *p*H. Conditions same as in legend of Fig. 1

the original mixture was streaked. Also no difference in mobility was observed when the pigments were first isolated by means of column chromatography (performed with cellulose powder and *n*-butanol : acetic acid : water, 40 : 10 : 12·5 v/v) and then subjected to electrophoresis. The pigment which travelled the fastest in chromatography moved the slowest in acidic electrophoresis.

Consequently, the original mixture was deemed adequate for ascertaining the electrophoretic mobilities at various *p*H's and the isoelectric points of the individual cherry pigments. The mixture was further dried *in vacuo* to a syrupy mass, which was then diluted with 0·03 *M* phosphate buffer of various *p*H's and streaked on the strip apparatus. After electrophoresis under the conditions described in the legend of Fig. 1, the apparent electrophoretic mobility (not the real mobility of the molecules in the tortuous path of the paper capillaries) was calculated. The electro-osmotic correction was estimated for each *p*H by means of the dextran indicator as described by Kunkel and Tiselius[4]. The corrected values are graphically presented in Fig. 2. It appears that the isoelectric point of pigment *A* is 6·9 and that of *B*, 6·0.

To test the hypothesis that the isoelectric point and the *p*H of minimum colour display coincide, the electrophoretically isolated cherry anthocyanins were dissolved in 1 *M* citric acid–sodium hydroxide buffer of various *p*H's, and the absorption spectrum of the solutions was measured by means of a Beckman *DK*-2 recording spectrophotometer. In the red region (500–530 mμ) in which these pigments show a maximum of absorption, the least optical density was found to be very close to the isoelectric point, as is indicated in Table 1.

Since the Montmorency cherry anthocyanins have been characterized[5], it was easy to identify the electrophoretic fractions *A* and *B*. Both paper chromatography and the sodium carbonate test[6] indicated that pigment *A* is the mecocyanin and pigment *B* the antirrhinin of Li and Wagenknecht[5].

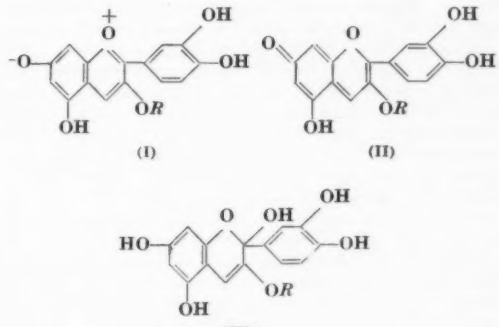
Table 1. Optical Densities at 520 mμ of the Montmorency Cherry Anthocyanins in Sodium Citrate Buffer at Various *p*H's

*p*H	Anth. *A*	Anth. *B*
3·0	0·678	0·688
4·0	0·160	0·155
5·0	0·124	0·108
5·5	0·106	0·105
6·0	0·088	0·098
6·5	0·085	0·110
7·0	0·084	0·119
7·5	0·086	0·120
8·0	0·087	0·122

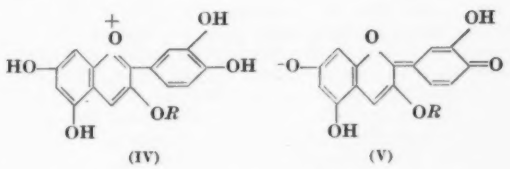
Experiments in progress on the separation of anthocyanins by paper curtain continuous electrophoresis are encouraging.

In view of the findings described, paper electrophoresis appears as a promising method of separation, purification, characterization and preparation of anthocyanins. It is still unknown, however, whether it will be as widely applicable as the chromatography of these pigments.

From the structural point of view, the formulæ proposed by Ingold[7] and Sondheimer[8] may account for the electrophoretic and chromatic behaviour of the anthocyanins studied. At the isoelectrical point of antirrhinin, for example, all eight of Ingold's forms—four tautomers differing in the distribution of the phenolic protons, each tautomer being mesomeric between a betanoid and a quinonoid form, such as the pair I and II—and Sondheimer's pseudobase III



can explain the electrophoretic immobility; the pseudobase, however, may be the dominant form, since its interrupted conjugated bond system is more compatible with the lack of colour at this *p*H. On the acidic side of the isoelectric point, form IV should prevail, although the rather unstable oxonium forms involving the phenolic oxygens may be present. At *p*H higher than the isoelectric point, the oxonium configuration probably disappears and the negatively charged tautomers of type V constitute the dominant forms.



Acknowledgment is made of the technical assistance of Miss S. Krishna.

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USE OF FERRITIN-CONJUGATED ANTIBODY TO LOCALIZE ANTIGEN BY ELECTRON MICROSCOPY

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THE conjugation of ferritin with globulin, as described by Singer[1], provides a reagent which allows adaptation of the basic principle of immunofluorescent staining[2] to electron microscopy. The ferritin molecule, a protein of molecular weight about 700,000, contains a central core, 55–60 Å. in diameter, of four ferric hydroxide particles which are sufficiently dense to be readily identified in electron micrographs[3–5].

Horse spleen ferritin[6,7] (supplied by courtesy of Dr. A. Mazur, Cornell University Medical College, and the Sylvana Chemical Co., Orange, New Jersey) and antibody globulin[8] were conjugated according to Singer's method[1] with minor modifications, as follows: 4 ml. of a 1·8 per cent solution of purified amorphous ferritin were mixed with 2 ml. of 0·3 *M* borate buffer (*p*H 9·5) to achieve a final 0·1 *M* buffer solution. 0·12 ml. of *m*-xylylene di*iso*cyanate (supplied by courtesy of the Carwin Co., North Haven, Conn.) was added, the mixture was stirred for 45 min. at 0° C., left to stand 1 hr. and centrifuged for 30 min. in the cold. The supernatant was removed from the unreacted xylylene di*iso*cyanate, which was discarded. The ferritin–xylylene *iso*cyanate complex and the immune globulin were mixed on a weight-for-weight basis and buffered with 0·1 *M* borate buffer. Sodium chloride was added to 1 *M* concentration. The mixture was stirred at 4° C. for 48 hr., dialysed against 0·1 *M* ammonium carbonate overnight and dialysed an additional two days with 0·1 *M* phosphate buffer (*p*H 7·5). It was then centrifuged, the supernatant passed through a 'Millipore' filter and stored for use.

In order to ascertain the effect of conjugation on the reactivity of antibody with its homologous antigen, a hæmagglutination system with conjugated antibody to purified bovine serum albumin was used. By means of Boyden's technique[9], as modified by Heller *et al.*[10], tanned sheep erythrocytes were coated with bovine serum albumin and exposed to serial dilutions of ferritin-anti-bovine serum albumin. It was found that conjugation with ferritin did not reduce the hæmagglutinin titre of the anti-bovine serum albumin globulin. The agglutinated red cells were washed, lysed with saponin, washed again repeatedly and dried from suspension on 'Formvar'-coated grids. Electron microscopic examination revealed numerous ferritin particles on the red cell stromata. Controls included unconjugated anti-bovine serum albumin globulin mixed with ferritin, a non-specific ferritin-conjugated antibody (rabbit anti-pneumococcus type 15 globulin) and purified ferritin alone.

The technique was applied to the identification of viral antigens in tissue using influenza virus, *PR*8 strain, which was inoculated by the allantoic route into 11-day-old chicken embryos. After incubation at 35° C. for 44–48 hr., portions of infected chorioallantoic membranes, still attached to the egg shell, were placed for 1–60 min. at room temperature in ferritin-conjugated chicken anti-*PR*8 globulin which had been absorbed overnight with acetone-extracted chicken embryo powder. (This anti-*PR*8 globulin had not lost any appreciable hæmagglutinin-inhibition titre in the course of conjugation with ferritin.) After washing in Tyrode's solution the membranes were detached from the shell, fixed for 20 min. in buffered osmium tetroxide, dehydrated in graded dilutions of ethanol, trimmed, embedded in N-butyl methacrylate, sectioned on a Porter–Blum microtome and examined in an R.C.A. *EMU-2E* electron microscope.

In work using the fluorescent antibody technique, it has been repeatedly demonstrated that in the course of influenza and fowl plague infection viral antigen eventually concentrates at the cell surface[11–13]. Previous work in this laboratory has elucidated the morphology of the virus and shown that it differentiates at the cell surface of the infected chorioallantoic membrane[14]. Fig. 1 illustrates a thin section through the superficial portion of a chicken chorioallantoic cell infected with *PR*8 influenza virus and afterwards exposed to ferritin-conjugated anti-*PR*8 globulin for 1 hr. (Subsequent experiments have shown that optimal specific tagging of the virus is achieved in 2 min.) The limiting membrane, which traverses the lower border, has been cut obliquely and is therefore poorly defined. Extending upward into the chorioallantoic space is a cellular protrusion. On the cellular surface are scattered oval viral particles which exhibit a poorly defined core, a dense limiting membrane and a diffuse outer coat. Serial sections[14] have shown that structural appearance of the particles depends on the level at which they are cut: they are relatively dense and sharply

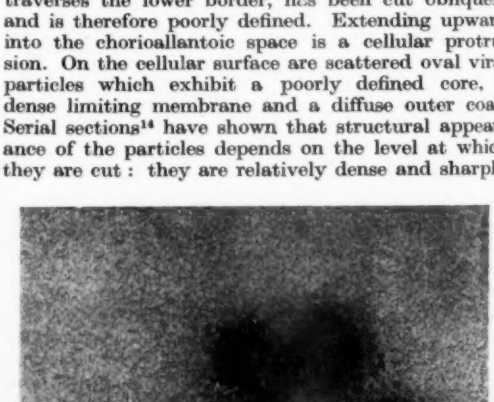

Fig. 1. Influenza virus at the cell surface. Ferritin granules associated with the viral particles are clearly visible. (×170,000)

* Fellow of the National Foundation.

defined when sectioned centrally, but appear less dense and more diffuse when the plane of section is eccentric. The opaque, sharply defined ferritin granules are attached to the diffuse outer coat of the virus. As may be seen in several instances, ferritin overlies the viral particle when it is eccentric to the plane of section. It is likely that with our present methods all the antibody is not conjugated with ferritin and hence determination of the precise arrangement and number of antigenic units on the viral surface must await further study. As a control to the foregoing experiments, chorioallantoic membranes were infected with the Lee strain of influenza virus and treated in an identical manner with ferritin-conjugated anti-*PR*8 globulin. Although a few scattered ferritin granules were present on these cells, there was no predilection for the viral particles. Likewise, *PR*8-infected membranes exposed to other non-specific ferritin-conjugated antibodies (rabbit anti-pneumococcus type 15 globulin and duck anti-rabbit-globulin globulin) showed only sparse and randomly distributed ferritin particles. Further to document the specificity of the reaction, *PR*8-infected membranes were exposed to unconjugated anti-*PR*8 globulin for 1 hr., then washed and placed in ferritin-conjugated anti-*PR*8 globulin for 2 min. This resulted in no localization of ferritin on the virus, whereas an infected membrane exposed for 1 hr. to normal serum before immersion in ferritin-anti-*PR*8 globulin showed characteristic tagging of the virus.

It appears that ferritin-conjugated antibody globulin maintains its serological specificity and thus renders visible in the electron microscope the sites of antigen–antibody interaction. Within the limits of these experiments it has been shown that tagging of virus with ferritin-conjugated antibody is specifically blocked by prior treatment with unconjugated antibody globulin. Work is in progress to modify the technique so that identification and localization of intracellular antigens may become possible.

These investigations were conducted under the auspices of the Commission on Influenza, Armed Forces Epidemiological Board, and were supported in part by the Office of the Surgeon General, Department of the Army, Washington, D.C., by a grant from the National Foundation, and USNIH grant *H*-3929*C*.

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IMMUNOLOGICAL RELATIONSHIPS BETWEEN THE RAT GLOMERULUS AND NEPHRITOGENIC STREPTOCOCCI

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FOR many years efforts have been made to establish an experimental counterpart for human glomerulonephritis utilizing the streptococcus or its products without notable success. The most recent, by Kelly and Winn[1], employed an intraperitoneal diffusion chamber containing Group *A*, type 12 streptococci. These workers reported that such a procedure led to the establishment of glomerular lesions.

Utilizing such chambers, approximately 10^8 cells of an 18-hr. culture grown in Todd–Hewitt broth were introduced and the side arm sealed off by heat-fusing a polyethylene tube. Strains *NAC*, *NV* and *NVC*, Group *A*, type 12 streptococci were obtained through the generosity of Dr. Elizabeth Potter, Dept. of Medicine, Northwestern Medical School. All strains were originally isolated from the throats of acute glomerulonephritic patients. The chambers were inserted into the peritoneal cavity of female, Holtzman strain rats weighing 150 gm.; removed after 72 hr. and the animals killed one, two, and four weeks from the date of insertion of the chamber. In all instances the kidneys appeared both grossly and histologically normal, that is, within the limits of histological variation in normal rats which show focally increased cellularity of glomeruli and rare casts within tubules. Especially within this context, histopathological interpretations have been made initially by several observers without prior knowledge of the experimental procedure employed and afterwards reviewed in the light of such knowledge. (We are indebted to Dr. Paul B. Szanto, director of pathology of Cook County Hospital, for his critically cautious counsel in histological interpretation as well as for the support of his department's facilities.)

Studies of the virulence of the strains employed revealed no useful LD_{50}, since 10^8 cells failed to affect a single mouse. Virulence enhancement by means of mouse passage was then instituted with one of the strains, *NAC*. The first passage required intraperitoneal introduction of the organisms with an equal volume of a 5 per cent suspension of hog gastric mucin in order to obtain sufficient numbers of bacteria for subsequent splenic homogenate transfers. After 27 passages the *NAC* strain presented an LD_{50} of 10^2 and was then sub-labelled NAC_v.

Introduction of the NAC_v strain into the chambers, implantation for 72 hr. and killing of a group of 12 rats at four weeks consistently produced lesions the maximum degree of which is illustrated in Fig. 1. (A representative glomerulus from a control animal is illustrated in Fig. 2.) The glomerular lesions never approached, either in intensity or in diffuseness, those we have seen in initial biopsies of streptococcal related acute glomerulonephritis in the human. The spotty glomerular changes were uniformly accompanied by eosinophilic casts both in proximal and distal convoluted tubules in numbers far in excess of those seen in control animals.

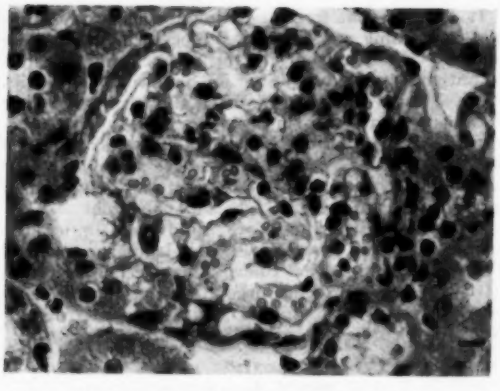

Fig. 1. Cellular, swollen glomerulus. Filling out of Bowman's space with free red cells in space; sparse polymorphonuclear leukocytes in glomerular tuft. (×c. 360)

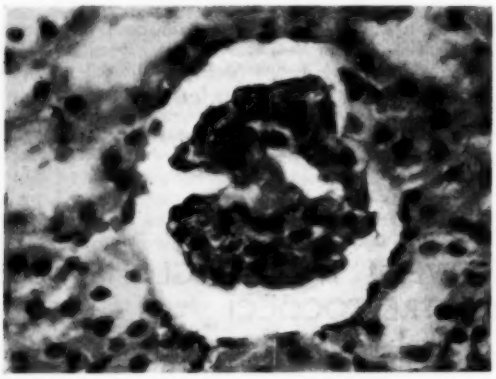

Fig. 2. Normal glomerulus. (×c. 360)

Subsequent to these experiments an additional strain, A_{12}-41, was obtainedwhich after five passages in mice had an LD_{50} of $2{\cdot}5 \times 10^1$ and within peritoneal chambers induced similar histological changes in a group of 12 animals. (We are indebted to Dr. J. Hayashi, Department of Biochemistry, University of Illinois Medical School, who obtained this Red Lake strain for us through the courtesy of Dr. W. Schmitt of the Cuyahoga County Hospital, Cleveland, Ohio.)

The virulent state of these two strains was maintained by quick freezing (acetone-'dry ice') a 1-ml. broth suspension in ampoules and storing in the cold at −15° C. For diffusion chamber experiments the content of the ampoule was permitted to thaw at room temperature and transferred to a tube of Todd–Hewitt broth. The resultant 18-hr. culture was then introduced into the chambers.

Based upon the results presented above, no satisfactory conclusion could be reached as to the genesis of the renal lesions, that is, toxic or immunological. It has been suggested by one of us (A. S. M.) that the nephritogenic streptococcus and the glomerulus may share an antigenic component in common. Accordingly, an extraction procedure was elaborated in an effort to isolate a soluble, antigenic component from the streptococcus capable of inducing the formation of nephrotoxic antibody.

Whole, heat-killed, washed, 18 hr. old A_{12}-41 cells (progeny of quick-frozen cells) were suspended in phosphate buffer, *p*H 8, and trypsinized for 4 hr. at 37° C. The supernatant, after removal of particulate matter by centrifugation and Seitz filtration, was treated with an equal volume of 'Genetron' (trifluorotrichloroethane) in the manner of Markowitz and Henderson[2]. The aqueous phase of this treatment was dialysed against water in the cold for 24 hr. and then lyophilized. Rabbits were immunized with 75 mgm. of the extract combined with Freund's adjuvant and the serum obtained was assayed for nephrotoxic activity in the rat. Serum dosages of 0·01 ml. per gm. of body-weight were introduced into the tail veins of a group of 12 rats. Equivalent amounts of control rabbit serum (obtained from animals immunized with Freund's adjuvant plus 0·89 per cent sodium chloride solution) were likewise introduced into a similar group of animals. Fig. 3 represents the most pronounced of glomerular lesions observed in the experimental group killed two weeks after introduction of serum. The sparse focal distribution of such glomeruli, in contrast to the clearly abnormal numbers of tubular casts (also illustrated in Fig. 3), cannot be overemphasized. The group receiving control rabbit serum presented normal renal histology within the range indicated earlier.

Using isolated whole rat glomeruli prepared according to Greenspon[3] as the starting material and the same extraction procedure indicated above, a material was

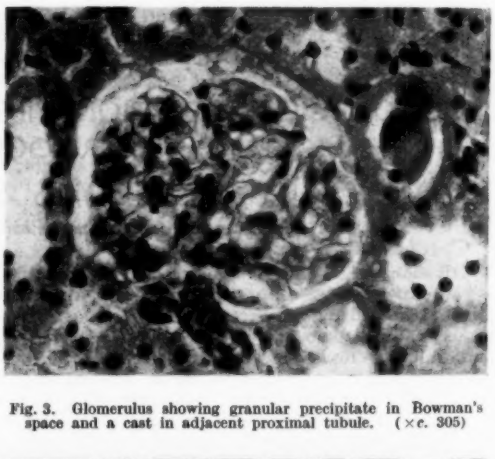

Fig. 3. Glomerulus showing granular precipitate in Bowman's space and a cast in adjacent proximal tubule. (×c. 305)

Fig. 4. Moderately hypercellular glomerulus, bridging of Bowman's space; swollen perithelial cells. (×c. 315)

obtained which also stimulated production of a nephrotoxic antiserum. The assay, which was conducted in a group of 12 rats, again revealed that the maximal glomerular changes (illustrated in Fig. 4) were of modest degree and focal in distribution; many glomeruli in the experimental animals could not with reliability be distinguished from glomeruli in certain control animals, while a clear distinction between experimental and control groups could be made by reason of numbers of casts and other tubular differences in the former. All three groups of experimental animals displayed proteinuria greatly in excess of control animals.

Based upon electrophoretic analysis of the extracts which indicated heterogeneity and the focal and modest character of the glomerular lesions in the experimental animals, the necessity for more potent antisera directed against further purified, monospecific entities is recognized.

It would appear from the observations presented in this preliminary communication that the diffusion-chamber-streptococcus induction of experimental glomerulonephritis has probably an immunological basis and that common antigen(s) may be shared between the nephritogenic streptococcus and the rat glomerulus. Additionally, there is a clear-cut relationship between the virulence and the nephritogenic capacity of our strains.

This work was supported by the Elizabeth McCormick Research Foundation. The senior author wishes to express his appreciation to the Board of Commissioners of Cook County and to Warden Fred A. Hertwig, Cook County Hospital, for their interest and development of facilities for basic medical research.

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BEHAVIOUR OF PAPER DURING TENSILE STRAINING

By A. E. RANGER and L. F. HOPKINS

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FOR many years the view has been widely held that the final fracture in the tensile testing of paper is governed by failure of inter-fibre bonds, and that very few of the fibres themselves are actually broken. Recent work by Van den Akker[1], however, in which individual fibres in the failure region could be observed, has cast doubt on this belief. Of those fibres involved in the fracture a high proportion was found to be ruptured—as many as 77 per cent in one instance. Although Van den Akker is careful to point out that many of the fibres failed after the paper had started to fracture and that such fracture could still be initiated by bond failure, he nevertheless concludes that: "the strength of the fibres of a papermaking pulp is of much greater importance than had hitherto been generally recognized".

A critical analysis of the evidence in favour of inter-fibre bond failure as opposed to fibre failure had led us, independently, to the same conclusion and to attempt to describe the tensile behaviour of paper on a basis of predominance of fibre failure.

A difficulty arose at the outset when considering the increase in optical opacity which occurs during the plastic stage of straining. Although generally accepted as indicating fracture of inter-fibre bonds, this change could also be due to the rupture of fibres. Experiments designed to detect such pre-fracture damage were carried out, but with negative results.

A way was therefore sought of reconciling the two apparently contradictory ideas—that of inter-fibre bonds being broken during the straining process, and that of the final fracture being predominantly governed by fibre failure.

During the course of previous experiments it had been established that a paper strip undergoing longitudinal extension contracts significantly in width. One effect of this is that fibres oriented approximately at right angles to the direction of tension are subjected to longitudinal compressive forces. It is suggested that, because of their slenderness, these fibres will tend to buckle at comparatively low strains, and in so doing will tend to peel apart from those fibres which are, because of their orientation, held in tension. Such a process can occur at a much lower stress-level than rupture by simple shear, which is the predominant mode of failure of those bonds which are ruptured at final fracture of the paper. The complete picture, then, is of the tensile strength of the fibres being intermediate between two effective bond 'strengths' which differ by virtue of the two distinct modes of rupture.

This proposed mechanism of bond failure during plastic straining has been invoked to explain the phenomenon of strain lines. When a strip of tracing paper is strained, the increase in opacity can be followed visually, and it is seen that the opaque regions form a reticulate pattern orientated at a characteristic angle to the direction of tension. Rance[2], who first directed attention to these strain lines, also demonstrated their existence in other types of paper by a method analogous to the brittle lacquer technique in stress analysis, which incidentally showed that they are regions of high local deformation.

The failure of a small group of bonds by peeling will raise the stress-level in the immediate vicinity and give rise to a band of local deformation; but if the relative movement of the two parts of the paper is parallel to the direction of tension the deformation

will be limited, since there will be no tendency for further fibre buckling to occur. In addition, a simple analysis shows that the deformation band in this case would be perpendicular to the direction of tension, which contradicts experience.

However, if the two parts of the strip tend to separate by a shear or slip movement along the band of deformation itself, these difficulties do not arise. Such movement would automatically subject more fibres to compressive forces and lead to further bond failure by peeling.

An analysis of the situation was made, based on this assumption of shear movement, which led to a prediction of the angle at which such a band of local deformation should occur. An 'orientation factor' was included in the analysis to facilitate comparison with machine-made paper, which is anisotropic with respect to fibre orientation. Fig. 2 shows the predicted variation of strain-line angle with strip direction, the angles being defined in Fig. 1.

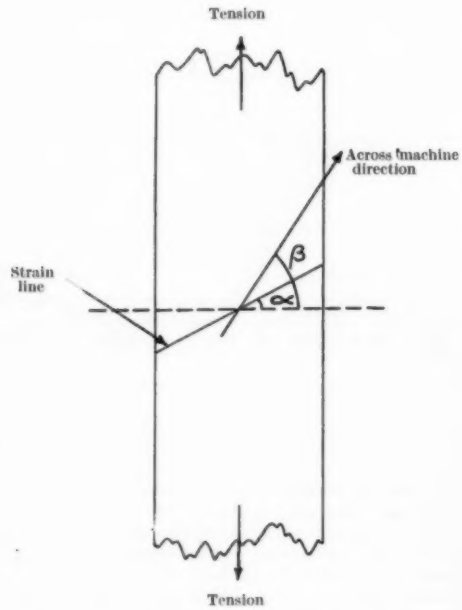

Fig. 1. Orientation of strain line and machine direction with respect to test strip

In view of the assumptions made in the mathematical treatment and the uncertainty involved in the degree of fibre orientation in machine-made paper, the agreement in the case of tracing paper is perhaps not unsatisfactory, especially since in this instance it is not possible to verify the complete variation of strain-line angle because the pattern becomes indistinct as the machine direction is approached and the angles can no longer be measured. However, the proposed mechanism of formation of strain lines, despite its genesis, does not apply only to strong papers, and it was found that very weak papers (for example, from an unbeaten pulp) tended to fracture along a diagonal line which was tentatively identified as a strain line. A technique evolved from this observation whereby strips of strong machine-made paper were wetted locally and thus weakened excessively and the angle of the fracture was measured. By this means the complete variation of 'strain-line' angle could be investigated, and this result also is shown in Fig. 2.

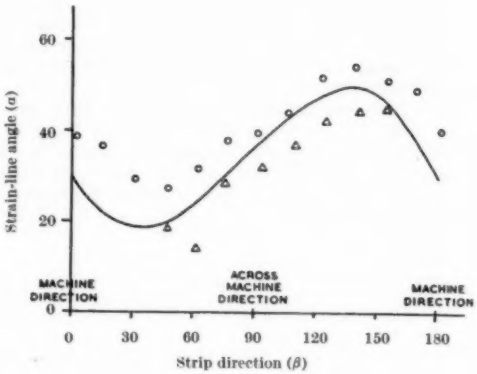

Fig. 2. Variation of strain-line angle with strip orientation. △, tracing paper; ○, wetted Kraft paper (fracture angle); —, theoretical curve

Wetted strips also show quite clearly the shear movement at fracture and the local increase in paper thickness caused by the buckling of fibres (Fig. 3).

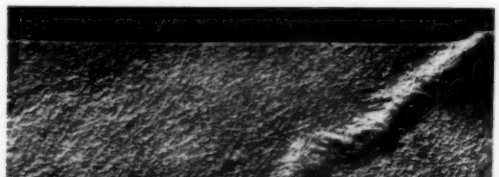

Fig. 3. Shear movement and local increase in thickness with wetted paper

This theory of paper behaviour during tensile straining leads to several interesting predictions which are being investigated, and it is hoped to present a full account of this work in September 1961 at the Fundamental Research Symposium which is being organized by the Technical Section of the British Paper and Board Makers' Association.

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LETTERS TO THE EDITORS

PHYSICS

Pulse-shortening in Electron Linear Accelerators

During the past few years several electron linear accelerators have been designed in Great Britain, France and the United States to support pulse currents in excess of 250 m.amp. for durations of 1–10 μsec. Many of these machines have failed to reach design performance due to a phenomenon which has come to be known as 'pulse-shortening'. This effect appears as a premature termination of the output electron pulse and occurs at pulse currents in the range 300–600 m.amp. and pulse-lengths of 1 or 2 μsec. depending on the particular machine. Further increase of pulse current is possible only at the expense of pulse-length. The current pulse and the radio-frequency loading are normal until the point in time at which 'shortening' occurs. Beyond this point, where there is typically a 0·1/0·2 μsec. jitter of the trailing edge of the current pulse, there is little or no electron current and usually the radio-frequency pulse shows an increase somewhat above the normal loaded level but does not reach that corresponding to zero beam.

The values of current quoted above refer to the onset of pulse-shortening at the *S*-band (3,000 Mc./s.). At least one machine constructed in the United States operates on the *L*-band (1,250 Mc./s.) and is reported as exhibiting pulse shortening but at much higher pulse currents (1–2 amp.). Conversely *X*-band (9,250 Mc./s.) accelerators designed in this laboratory have shown this effect at about 40 m.amp. It would appear that for accelerators operating at different frequencies but of similar energy gain and length the current obtained at the onset of pulse-shortening is proportional to $1/f^2$.

Our experiments on a single accelerator section have shown that pulse-shortening occurs first at the high-energy (low radio-frequency power) end of the accelerator wave-guide, and that the buncher and first half of the accelerator are capable of supporting rather more than the design current and at least three times the current required to produce shortening in the last half. It has been shown also that the current at which pulse shortening occurs is proportional to the radio-frequency power-level in the accelerator tube. If the mechanism of pulse shortening is a 'field effect', we might expect to increase significantly the current obtainable by designing the guide to use feedback or more conveniently by the use of a constant-field design.

A 'constant-field' accelerator has been constructed to operate at the *X*-band and has yielded currents in excess of 100 m.amp. without showing pulse-shortening as compared to 40 m.amp. for the equivalent constant-impedance design. This increased current is normal and is limited by the radio-frequency power available.

If both 'constant-field' and 'feedback' accelerators yield this increased current it would seem that the pulse-shortening mechanism is a 'field' effect associated with low values of field in the normal mode. If, however, the 'constant-field' solution is the only successful one, then it appears that higher order spurious radio-frequency modes may be responsible, as has been suggested by other workers in this field. Investigations of the free space wave-length and type of such modes with a phase velocity equal to that of light have been made by K. W. Robinson, Cambridge Electron Accelerator Project (private communication), and W. Gallagher, Stanford University, California (private communication).

Further work on this problem is being carried out and will be reported shortly.

We wish to thank Dr. C. F. Bareford, managing director of Vickers Research, Ltd., for permission to publish these preliminary results of our investigations.

M. G. Kelliher
R. Beadle

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Berks.

Dependence on Latitude of the Amplitude of the Diurnal Variation of Cosmic Rays

The solar diurnal variation of cosmic-ray intensity is usually assumed to be due to the rotation of the Earth in a cloud of particles. The velocity of the latter should be randomly distributed with a small additional component in one direction, thus constituting a kind of particle wind. For various reasons it can be assumed that this wind is following the Earth, approximately parallel to its orbital plane[1]. The yearly mean amplitude of the diurnal variation should then have a maximum for primary particles having asymptotic directions approximately parallel to the equatorial plane. It should have a minimum for primaries with asymptotic directions parallel to the Earth's axis of rotation. For an experimental study of the relative magnitude of the amplitudes in these directions, it is necessary to record the variations of cosmic-ray intensity with inclined counter telescopes. However, it is difficult to gain access to both directions at one and the same point on the Earth's surface.

From the terrella experiments by Brunberg[2], it was found that one of the desired directions could be recorded with an inclined counter telescope at Uppsala, while the other direction could be recorded in the same way from a station in the Arctic. What seemed most promising, however, was the fact that not only could the two stations be linked together by a second directional telescope in each place, but also the station at Kiruna could serve as an extra link[3]. In August 1957 an Arctic station was erected at Murchison Bay, Spitsbergen.

Telescopes with a zenith angle of 30° could be used in all the three places. The telescopes at Uppsala (lat. 59·9° N., long. 17·9° E.) and Murchison Bay (lat. 80·1° N., long. 18·3° E.) should point in the east

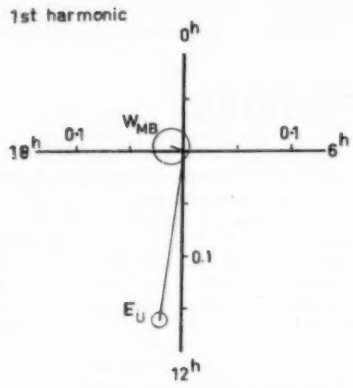

Fig. 1. Harmonic dial for the diurnal variation recorded by the east-pointing counter telescope at Uppsala (E_U) and by the west-pointing telescope at Murchison Bay (W_{MB})

and west directions, those in Kiruna (lat. 67·8° N., long. 20·4° E.) north and south. The axis of the east-pointing telescope at Uppsala corresponds to primaries entering the geomagnetic field in an asymptotic direction making an angle of 14° with the equatorial plane of the Earth. The axis of a west-pointing telescope at Murchison Bay corresponds to primaries making an angle of 82° with the equatorial plane. The values are approximate. They were derived from the assumption that the effective rigidity of the primaries[4] is 25 GeV./c. If instead the effective rigidity is assumed to be 35 GeV./c. the values will be 20° and 80°. Actually, the relation between the asymptotic directions, the axis of the counter telescope, and the rigidity spectrum cannot be calculated in a simple way[5]. However, in the present experiment, the angles of the two asymptotic directions differ in any event by such a considerable amount as to make the experiment decisive.

To secure the most reliable results, the harmonic analysis has been carried out for the mean daily variation during exactly the same days for the directions to be compared. Nevertheless, 312 days were available for the calendar year 1958. The harmonic dial in Fig. 1 suffices to show that the west-pointing telescope at Murchison Bay (W_{MB}) does not have an amplitude exceeding the standard error, whereas the east-pointing telescope at Uppsala (E_U) has an amplitude which is large compared to the standard error.

As regards the north- and south-pointing telescopes in Kiruna and the east-pointing telescope in Murchison Bay, the mean asymptotic directions make angles of 40–55° with the equatorial plane. The amplitudes of these intermediate directions are all slightly smaller than that of the asymptotic direction approximately parallel to the equatorial plane of the Earth (E_U). The primaries observed by means of the west-pointing telescope in Uppsala have asymptotic directions covering angles between 50° and 90°. The yearly mean amplitude is one-third of that of the direction parallel to the equatorial plane.

The results reported here clearly show that the amplitude of the diurnal variation decreases with increasing angle between the asymptotic direction of the primaries and the equatorial plane of the Earth. The fact that observations in two directions at the same point have given contradictory results[6] or failed to show any dependence on latitude[7] is certainly due to the difficulty in such cases in resolving the radiation cones of the primaries[8].

A full account of the present experiment will be published as soon as possible.

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Fractionation of Nuclear Weapon Debris

Edvarson *et al.*[1] report evidence for a fractionation effect noted in the radioactive analysis of samples of nuclear weapons debris collected in filters carried by a jet plane flying over central Sweden. Certain individual particles selected from the filters appeared to be rich in (zinc-90 + niobium-90) radiations and impoverished in ruthenium-103 radiations.

The purpose of this communication is to present a somewhat similar finding from an earlier study. At the time of one of the nuclear detonations at the Pacific Proving Grounds, gummed paper fall-out collectors were placed on platforms at various locations in the vicinity of the Eniwetok atoll. A few of these gummed papers were available for nuclear radiation analysis. There was a wide range of individual particle-sizes, but among the particles were some that were large enough (between about 0·3 mm. and 1 mm. diameter) to be picked off the gummed paper with tweezers. Eleven such particles were removed from two gummed paper collectors, five from a paper that had been twelve miles down-wind from the point of detonation and six from another paper that had been thirteen miles cross-wind.

Gamma-radiations from the individual particles fell into two groupings, one rich in (zinc-90 + niobium-90)

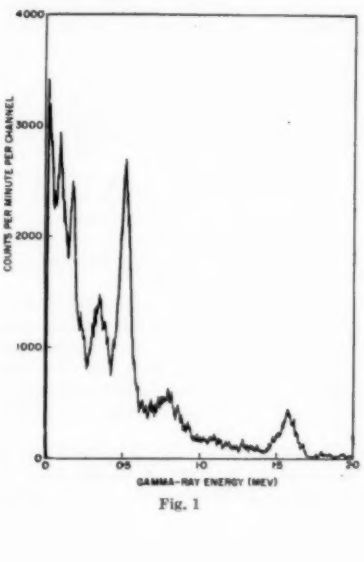

Fig. 1

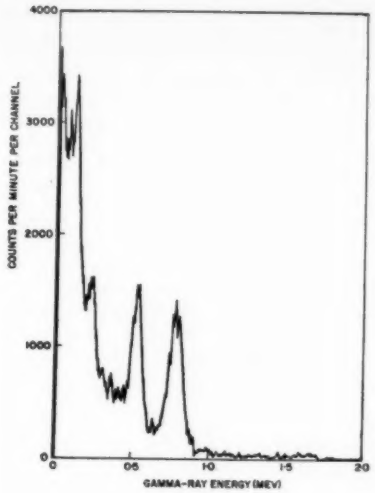

Fig. 2

radiations and the other essentially depleted of these radiations. Both types of samples were found at both stations. Pulse-height analyses, using a 4-in. diameter by 4-in. high sodium iodide (thallium) crystal, are shown in Figs. 1 and 2. Both sets of results were recorded 30 days after the detonation. It will be noted that in the spectrum of the particle from which the (zinc-90 + niobium-90) radiations at 750 keV. have been depleted, the 1·6 MeV. gamma-ray of lanthanum-140 can be observed; but this gamma-ray is not clearly distinguishable in the spectrum of the particle enriched with zinc-90 + niobium-90. A gamma-ray at about 500 keV., presumably ruthenium-103, appears in both spectra, but in much larger relative amounts in the sample depleted of zinc-90 + niobium-90.

The assistance of Mr. E. Schuert in supplying the gummed paper fall-out collectors is gratefully acknowledged.

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Stepwise Ablation and Heat Transfer in Cold-Cathode Arcs

A 'cold-cathode' arc is an electric discharge in a gas or *in vacuo* with a cathode fall of about 10 V.[1] and a current density at the cathode of 10^5–10^6 amp./sq. cm.[1,2]; the intense light observed comes from the cathode vapour but not from the ambient gas, if present. The cathode temperature is much too low to give the high current density of electrons if emitted thermionically from the spot, but was thought to be high enough to produce copious evaporation; pyrometric and spectroscopic temperature measurements showed 2,000–2,500° K. for many metals[3–6].

If the loss of energy by thermal conduction from the spot into a copper cathode is calculated, it is found to be equivalent to 30–100 volts for currents $\leqslant$10 amp.—a range free of spot-splitting; thus such arcs could only be maintained by more than 30 V. Yet measured minimum arc voltages[3] suggest a loss of heat conduction from the active spot equivalent to a few volts. Against this view can be held that such low current arcs often last for a few seconds only[7]. Moreover, with 'selected' data the calculated conduction loss from a stationary spot with $i \geqslant 20$ amp. may be only $\simeq 4$ V.; but a moving spot would certainly consume many times that value[8].

To resolve this discrepancy a thin layer of low thermal conductivity (oxides) at the spot has been postulated[9]. With oxide-free electrodes, however, the arc voltage differs little, and so one is led to doubt that the measured temperature is that of the cathode spot. In fact the real spot temperature may be much lower[5] than 2,000° K. or so, as found with mercury; there is the dense cloud of luminous metal vapour covering it[1]. If this were so, the existence of this narrow region of dense vapour above the spot—a requirement of the new arc theory[8]—cannot be explained in terms of classical evaporation; hence a new concept of evaporation must be invoked.

A similar argument applies to carbon cathodes in molecular gases[10], such arcs being stable for currents down to about 1 amp. at atmospheric pressure. As the gas pressure is gradually reduced, cathode temperature and cathode fall decrease steadily until at pressures <100 mm. mercury the thermionic spot suddenly changes into a vapour spot, with its characteristic mobility, high current density, emission of spectral lines of carbon, intense ablation and deposition of carbon on the walls of the vessel (our unpublished measurements). Again from this and other observations[10,11], one is forced to conclude that the conventional evaporation picture is untenable.

A pointer to a new solution seems to be the large energy flux from the gas into the spot maintained by unexcited and excited neutral particles, and by ions and quanta. Some of these species may ablate the cathode by a step-wise process: a lattice atom absorbs (and can re-emit) several small amounts of potential energy from incident species, and moves from its original site through intermediate positions into a final position which corresponds to an energy close to that of the boundary. From this it ultimately escapes into the gas phase[12]. A special case would be the presence of a single intermediate energy-state, analogous to a strongly adsorbed layer[12]. The concept of stepwise ablation thus involves the transfer of potential energy, and is therefore very different from that of sputtering by fast ions, for example, through momentum transfer, or classical evaporation through lattice vibrations.

The use of the new model has several consequences. First, a number of species, each of energy less than the evaporation energy λ, can between them release an atom from the lattice. Secondly, by introducing these intermediate energy-states, the flow of heat into the metal matrix can be greatly decreased.

Thus, if n species each of energy e_0 fall on the spot per cm.^{2} and sec., classical theory of coupled oscillators shows that evaporation (into 2π) occurs at a rate:

$$(2\lambda/kT)\ (\nu/A)\ \exp(-\lambda/kT)$$

T being the absolute temperature of the lattice determined by heat input, conduction and evaporation, ν the frequency of lattice vibrations, and A the area[12]. Hence only a small fraction of ne_0 con-

tributes to evaporation, and the larger part to conduction, etc. However, with a two-stage ablation process (e_1, e_2 being the energy difference: intermediate state—vacuum and matrix—intermediate state respectively, and z_1, z_2 the corresponding transition probabilities) the energy balance in the steady state with $(e_1+e_2) > e_0 > e_1, e_2$ is:

$$ne_0 = nz_1e_1 + n(1 - z_1)z_2e_2 + H$$

where H is the conduction loss, and $(e_1 + e_2) = \lambda$. Terms relating to electron emission, etc.[8], have been omitted for clarity.

Since z_1, z_2 have a value between 0 and 1, H is clearly smaller than in the absence of an intermediate state, when z_1 or $z_2 = 0$. A similar argument applies when $e_0 > \lambda$, as direct evaporation is thought to be unlikely[12]; when $e_0 < e_1$, e_2, classical theory holds.

We conclude that step-wise ablation may explain a high rate of vapour production with low loss of heat by conduction when fairly slow-moving excited particles or low-energy quanta supply energy to a cathode. Moreover, this approach may be of interest to current work on accommodation coefficients and bear on the origin of fast-particle streams emanating from arc electrodes[14,15].

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ASTRONOMY

Origin of the Solar System

In a recent communication[1], Dr. M. M. Woolfson has outlined a model to account for the origin of the solar system. In common with many earlier hypotheses[2], he postulates an interaction between the primitive Sun and a second star. By gravitational interactions he proposes that the Sun lost a large amount of surface matter by the breaking away of tidal bulges. This matter is envisaged to have been lost in a series of isolated events and the resulting separate sections gave rise to a planet.

While there can be no doubt that this model accounts for many of the observed regularities of the solar system, there seem to be other features that are not explained. The latter appear incompatible with any catastrophic account of planetary origins.

First, there are the known properties of meteorites[3], which indicate that the early history of the solar system was most complex and that the present planets are second—or possibly third—generation structures that were preceded by objects of approximately planetary dimensions that have broken up.

Secondly, the densities of the planets (Table 1) indicate considerable fractionation of the chemical materials from which the former arose. On catastrophic hypotheses, it is difficult to see how such fractionation could have occurred as each planet is postulated to have arisen from the same material—the solar surface.

Table 1

Planet	Semi-major axis (km.)	Mean density (c.g.s. units)
Mercury	0·387	5·05
Venus	0·723	4·87
Earth	1·000	5·52
Mars	1·523	4·24
Jupiter	5·202	1·33
Saturn	9·538	0·71
Uranus	19·190	1·26
Neptune	30·070	1·61
Pluto	39·518	2 (?)

Thirdly, the comets are part of the solar system and are not derived from interstellar material. Consequently a satisfactory account of the origins of planets must also be able to account for the origins of comets—unless it be assumed that comets are secondary features of the solar system that arose late in its history. Hypotheses postulating an evolution of the solar system from a solar nebula appear to be able to account for the origins of comets with the minimum of *ad hoc* axioms.

Other arguments that can be levelled at catastrophic hypotheses such as that outlined by Woolfson concern the improbability of forcibly ejected solar material condensing into solid planets, and the probable frequency of occurrence of solar systems in the Galaxy.

Material drawn from the Sun must be for long periods well within the Roche limit, and rapid dissipation by the action of gravitational forces would be predicted. Moreover, as Spitzer[4] has pointed out, the material would be initially at very high temperatures and pressures, and would expand under its own internal pressure and become dissipated. Consequently the prime requirement of any new catastrophic hypothesis must be a satisfactory explanation of how the ejected solar material could form into planets.

If the solar system had a catastrophic origin by a close interaction of two stars, then planetary systems must be very rare in the universe. In fact, the chances are that only the Sun and the star with which it interacted possess planets. Yet there is a growing body of evidence for the existence of extra-solar planetary systems, and there can be no doubt that many nearby stars are accompanied by dark bodies of approximately planetary size[5]. Thus, unless it be suggested that the solar system arose by one improbable mechanism while other planetary systems arose by other means, the catastrophic hypothesis is rendered very unlikely.

It would seem that the most that an interstellar interaction could have achieved is the production of a solar nebula from which the planets could have evolved; but the bulk of available evidence is against this view, as other more likely mechanisms have been

suggested to account for the origin of a nebula from which planets could have been formed[6].

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METEOROLOGY

Change of the Chlorine : Sodium Ratio in the Atmosphere with Altitude and Distance from the Source of Sodium Chloride, and the Distribution of Atmospheric Nitrate over the United States

The change of the chlorine : sodium ratio in rain-water with inland distance from seas is a well-known phenomenon. The experimental evidence available has lately been discussed by Eriksson[1], while further data on an almost continental scale have been supplied by Junge and Werby[2]. The latter measurements were recently used by Papée and Smith for an evaluation of trends between components of rain-water and physical variables[3]. From those computations, an indication of a decrease in the ratio between chlorine and sodium with the altitude of the sampling stations became available, and it was pointed out recently to one of us that a semi-empirical evaluation of the phenomenon might be of interest to workers in mountainous countries. In view of the importance of the process in atmospheric chemistry in general, and especially because of the possible role of activated sodium chloride as nuclei of atmospheric precipitation[4,5], a further study of Junge's data with particular emphasis on this problem was made. Prior to a broader evaluation of the problem and to a laboratory study of the phenomena involved, some results obtained are reported in this communication.

(1) *The Chlorine : Sodium Ratio.* It is well known from observations by Rossby and Egnèr[6] that northern air masses carry aerosols of a low chlorine : sodium ratio. Examination of Junge's data shows, however, that this phenomenon which might result in a chlorine : sodium – latitude correlation is smaller in the United States than a strong altitude effect, although it shows in the concentration of nitrate in rain-water (see later). The effect of altitude can be tentatively explained by observing that the intensity of such radiochemical phenomena as may alter sodium chloride aerosols varies nearly exponentially with height[7]. If one assumes that the average yearly horizontal speed of the particle carried by winds does not change considerably from station to station (and therefore that the time which the particle needs to be carried from the shore or an inland salt source to the particular station, is proportional to the distance) the change of chlorine in the air may be expressed as :

$$\mathrm{d\,Cl} = -k\,\mathrm{Cl}\,(\exp \beta h)\,\mathrm{d}\,s \qquad (1)$$

where s is the distance from the source of particles to the station and h stands for the altitude of the route. s is calculated here from a map and along lines of path straight and orthogonal to Junge's sodium isolines, while both the effective altitude of station (h) and the average altitude of ground-level travel over path s ($\bar{h}$) are used for the height parameter. Values of ($\bar{h}$) are obtained from the map by planimetry of the path. Annual concentrations in gram equivalents $\times 10^5 \times$ l.$^{-1}$, miles and feet, are used for the chemical species, s and h, respectively.

At the shore or salt-flat point of origin of the particles, $s = 0$; and $\mathrm{Cl} = a\ \mathrm{Na}$, with a obtained directly from ref. 2. Integration of (1) leads to :

$$\log_e \left\{ -\frac{1}{s} \log_e \left(\frac{1}{a} \frac{\mathrm{Cl}}{\mathrm{Na}} \right) \right\} = \log_e k + \beta h \qquad (1')$$

It can be seen that (1′) depends on the ratio of components alone and not on their individual concentrations; constants β and k can be obtained by least squares and we find :

$$\beta = (1{\cdot}_{88} \pm 0{\cdot}9)\ 10^{-4}; \quad k = (1{\cdot}_{18} \pm 0{\cdot}2)\ 10^{-3}$$

It is evident that the true distance an air mass follows may differ substantially from our calculated values of s and that 'individual average speeds' will probably differ. While therefore a relatively large standard deviation of the chlorine : sodium function discussed above ($S.D. = 0{\cdot}22$ unit) may well be understood, it appears to be of interest that better consistency is found when parameter s is completely eliminated from the scheme. If altitude alone is assumed to govern the process, then :

$$\mathrm{d\,Cl} = -k\,\mathrm{Cl}\,(\exp k'h)\,\mathrm{d}\,h \qquad (2)$$

which, following a procedure similar to the one previously described, integrates to :

$$\log_e \left(\frac{1}{a} \frac{\mathrm{Cl}}{\mathrm{Na}} \right) = \frac{k}{k'} (1 - (\exp k'h)) \qquad (2')$$

When the exponential term in this equation is expanded in series (stopping at the 3rd term) and substituted, (2′) becomes linear in :

$$\frac{\log_e \left(\frac{1}{a} \frac{\mathrm{Cl}}{\mathrm{Na}} \right)}{h} \text{ and } h$$

Constants k and k' can thus be obtained by linear regression; Table 1 gives the results obtained together with standard deviations of the functions computed.

Table 1. Coefficients, Equation of Change of Chloride/Sodium in Rain-water with Altitude (Equation (2′))

Elevation	k	k'	$S.D.$ of chlorine : sodium $= f(h)$
h	$(7{\cdot}_{18} \pm 0{\cdot}8)\ 10^{-4}$	$(-3{\cdot}_{39} \pm 1)\ 10^{-4}$	0·156
$\bar{h}$	$(5{\cdot}_{88} \pm 0{\cdot}7)\ 10^{-4}$	$(-2{\cdot}_{61} \pm 1)\ 10^{-4}$	0·144

The expression $\frac{1}{a} \frac{\mathrm{Cl}}{\mathrm{Na}}$ is plotted against $\bar{h}$ in Fig. 1.

Since suitable corrections for other factors (such as potassium, latitude, etc.) which might have had an influence on the phenomenon investigated failed to

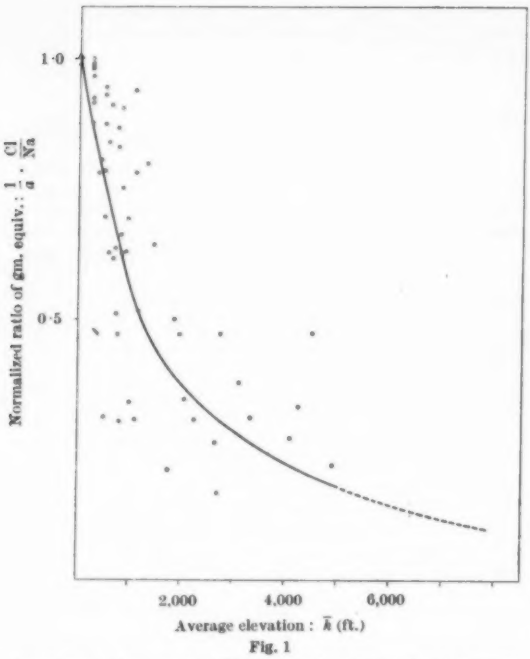

Fig. 1

improve the correlation, and since furthermore equations of type (2) appear to represent the process better than those of type (1) or other patterns considered, it may be thought that in the circumstances prevailing and in view of the large overland distances involved, the transformation of the sodium chloride aerosol must not only be relatively fast but also that it may proceed with a 'pseudo-reversibility'. This could be explained in terms of oxidation of chlorine[8] by factors increasing exponentially with altitude, which would cause a failure of detection of the new species by the chloride test to occur. The oxidized species, after having travelled down-slope, would afterwards be reduced by such atmospheric agents as may prevail at lower heights. An indication of the possibility of such a process may be obtained from the analysis of correlation coefficients between chemical species and altitude over the United States[3]. While in fact an increasing trend of calcium with h is indicated, and sulphate correlates with calcium, an increasing trend between sulphate and chlorine is suggested although both species have negative correlation coefficients with altitude. Second correlation coefficients of sulphate over calcium and chlorine ($r_2 = 0{\cdot}770$) and of chlorine over sulphate and h ($r_2 = 0{\cdot}483$) are both larger than absolute values of the individual components. We believe that this may be due in part to the oxidation of atmospheric hydrogen sulphide to free sulphuric acid aerosol, by products of oxidation of chlorine.

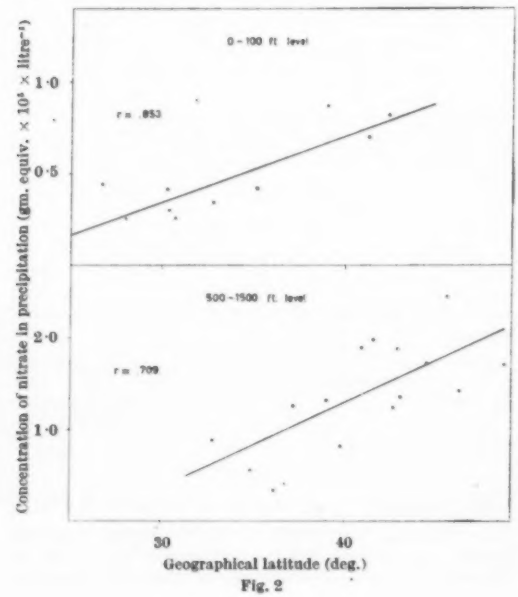

Fig. 2

(2) *Nitrate*. While at higher altitudes nitrate appears almost to be the complement of 'escaped' chlorine, a slight excess of the species over sodium and even over sodium + potassium can be detected at low levels. Plots of nitrate versus latitude for eastern United States are given in Fig. 2; significantly a positive correlation is obtained. The correlation coefficients decrease with altitude and eastward until quite low values for iso-altitudes in the Rocky Mountains are reached. It is possible that the cause of this is to be sought in patterns of atmospheric circulation and in such chemical processes as may be associated with phenomena dependent on geographical or perhaps, rather, geomagnetic co-ordinates.

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METALLURGY

A Symmetrical Fourfold Helical Fracture in Titanium Oxide

During the course of experiments on hot pressing powders of various hard, refractory materials, an interesting and apparently inexplicable fracture occurred in a specimen of titanium oxide. The general form of the fracture is shown in Fig. 1. It consists of four helices projecting as shallow cones. The specimen had also broken into four practically equal segments.

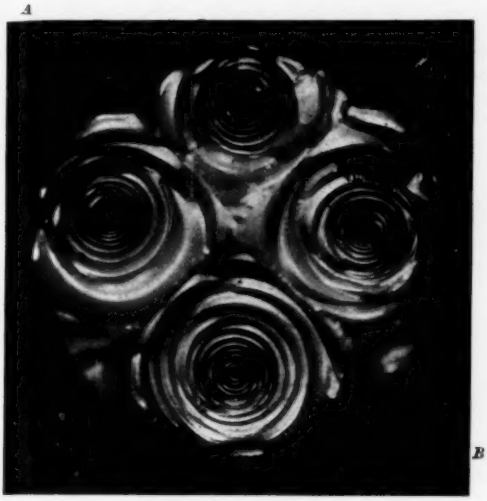

Fig. 1. Fractured surface of titanium oxide. (× 5)

The fracture arose during an attempt to separate the specimen from the cemented tungsten carbide plunger with which it had been pressed and to which it was adhering. Fracture took place almost entirely through the oxide, a layer of which, 0·5–1 mm. thick, remained adhering to the plunger. The second series of fractures, which is perpendicular to the plane of the paper, were normal in appearance. They can be seen in the form of an X with the arms at right angles.

On closer examination of the four helices it can be seen that the tip consists of a very small circle of carbide from the plunger. The helices are of almost identical form and size. Starting at a peak it can be seen that three of the helices are in a clockwise direction; the direction of the fourth is indeterminable. In Fig. 2 one of the helices is shown at a higher magnification.

The specimen was pressed from 98·5 per cent purity titanium dioxide of average particle size 0·2μ in a cemented tungsten carbide die ('Ardoloy S3') with a plunger of similar material. A pressure of 10 tons/sq. in. applied for 15 min. at 900° C. was used to produce a specimen $\frac{1}{4}$ in. in diameter approximately $\frac{1}{2}$ in. thick. To avoid difficulty in extraction from a cold die, the specimen was ejected while at the pressing temperature into a vessel containing fine aluminium oxide powder heated to 600° C. This could then be slowly cooled to prevent cracking the specimen through thermal shock.

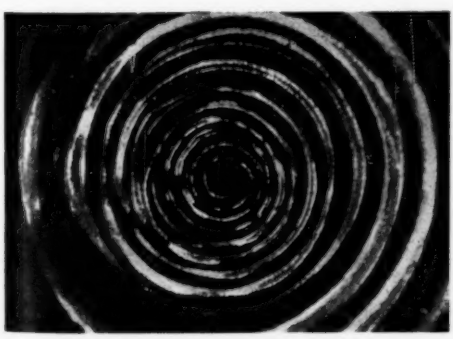

Fig. 2. Spiral fracture. (× 15)

Explanations could possibly be offered to account for the form of fracture shown by the individual segments. The mystifying feature in this case is that such a peculiar form of fracture should occur in a fourfold manner with such a high degree of exactness and symmetry.

The plunger and specimen had been separated by a bending action, the point of pivot being at *A* (Fig. 1) and the point of maximum tension at *B*, that is, in the direction of one of the vertical fractures. The face of the plunger had originally been ground but had become a mat surface through use.

The helical fractures had most likely started at the tip where the carbide adhered. It is possible that this was due to diffusion of material (most likely cobalt) from the plunger into the oxide, since the tips of the cones were also slightly discoloured beneath the level of the adhering carbide. There was no apparent reasen, however, for the diffusion to be more prominent in these four symmetrically arranged spots. Internal stresses arising through the rate of cooling and the dissimilar contraction coefficients of the plunger and oxide would no doubt be present apart from the bending stresses, but again could not account for the fourfold symmetry.

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Mode of Action of Soluble Matrix Antifouling Compositions

It has been demonstrated by Barnes[1] that the copper leaching-rates of antifouling compositions, based on the same soluble matrix, are proportional to the cuprous oxide content if the total matrix content remains constant.

Work being carried out in this laboratory has shown that the relationship is only correct when the antifouling compositions are stored in almost static sea water between leaching-rate determinations. If the sea water used for storage is agitated, then the leaching-rates of the compositions decrease with increasing agitation until they reach a constant minimum which is independent of the cuprous oxide content.

A possible explanation of these results is that under static conditions of storage the dissolution of copper is confined to particles of cuprous oxide partially embedded in the surface of the matrix; these particles produce a concentrated surface layer of copper ions which prevents any diffusion of copper ions from the matrix. Agitation reduces the ionic concentration of copper in the surface layer and also may remove all the particles of cuprous oxide exposed at the surface.

Under such conditions the leaching is due entirely to the diffusion of copper ions through and from the whole of the surface of the matrix (apart from areas occupied by fillers): it is independent of the cuprous oxide content and the rate depends mainly on the rate of reaction of the matrix. Increased agitation has little or no effect on the leaching-rate provided the

compositions are suitably pigmented to reduce mechanical erosion to a minimum. By increasing the temperature of the agitated sea water it has been shown that it is possible to increase the rate of solution of the matrix until it exceeds the rate of diffusion of the copper ions.

Under these conditions the leaching-rates again become proportional to the cuprous oxide contents.

These observations are considered to have an important bearing on the study of the performances of antifouling compositions on ships under way and in dock.

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CHEMICAL ENGINEERING

Control of Reaction Rate in Dust Flames

Ever since Nusselt[1] introduced the boundary layer concept, about forty years ago, for calculating rates of heat and mass transfer to a spherical particle, it has been universally accepted (without proof) by subsequent theoretical work (see ref. 2) that the reaction-rate of particles in a dust flame is determined by the rate of supply of oxygen through a diffusional boundary layer surrounding the particles. That this might not in fact be so was first suggested[2] about five years ago, the alternative proposition being that the rate control was chemical, not physical; the source of the implied error is attributed to the misinterpretation of reaction data in terms of diffusion instead of chemisorption which, according to Brunauer[4], has been a common mistake in the past. Support for the alternative hypothesis, however, has now been provided by analysis of experimental results obtained recently from an anthracite flame.

The experimental furnace or reactor has been described in outline elsewhere[5]; the flame generated by it may be regarded as a vertical cylinder, 18 in. in diameter and 15 ft. high, in which the particles travel paraxially downwards. The residual coke, mainly carbon formed by expulsion of volatiles, is brought up to temperature by burning these volatiles in primary air; the reaction we are chiefly interested in is then initiated by the 'instantaneous' introduction of secondary air at an appropriate point, and the subsequent reaction is followed down the furnace by solid sampling. Since anthracite is non-caking, complications from swelling are eliminated.

For theoretical analysis the material is assumed to be pure carbon. On the respective hypotheses of physical (diffusional) and chemical reaction control, the equations for specific reaction-rate (R_s) may be written respectively:

$$R_s = k_D/d \; ; \; R_s = k_c \qquad (1a,b)$$

where d is the particle diameter; and the factors k_D and k_c are both proportional to the concentration of the main stream of oxygen[6], and are both known functions of temperature (T). k_D contains the diffusion coefficient and therefore follows a $T^{\frac{3}{2}}$ law; and k_c contains the Arrhenius factor, $\exp(-E/RT)$. In the past, it has been assumed that k_c has a much greater temperature coefficient than has k_D. The source of this possible error was the wrong choice of value for E, the value of 40,000 cal. generally used being that for the decomposition of the adsorbed oxide film[7]. This decomposition process, however, only controls the reaction at low temperatures (less than 1,000° C.). At flame temperatures (greater than 1,000° C.) the rate of chemisorption becomes important, and if the assigned[3,4,8] value of the activation energy for this, namely, 4,000 cal., is valid, then k_c also approximates closely to a $T^{\frac{3}{2}}$ law.

Appropriate integration of equations (1) for a single particle in an infinite atmosphere gives the burn-out time (t_b) as a function of initial diameter (d_0); respectively, we get:

$$t_b = K_D.d_0^2 \; ; \; t_b = K_c.d_0 \qquad (2a,b)$$

where the burning constants K_D and K_c may be calculated from diffusion theory and kinetic theory respectively; their values are found to be of the order of 1,000 and unity. The validity of equation (2a), both with respect to the square law and to the value of the constant, has now been confirmed by experiments[9] on captive coal particles suspended in a radiation and low-intensity convection field, the particle sizes ranging from 300 microns to 4 mm.

In flames, however, a limited air supply increases the burning times. Following Nusselt[1] and others[10], the multiplying factors (F_D and F_c) for the two cases have been shown[9,5] to be calculable functions of excess air alone. These various functions have been

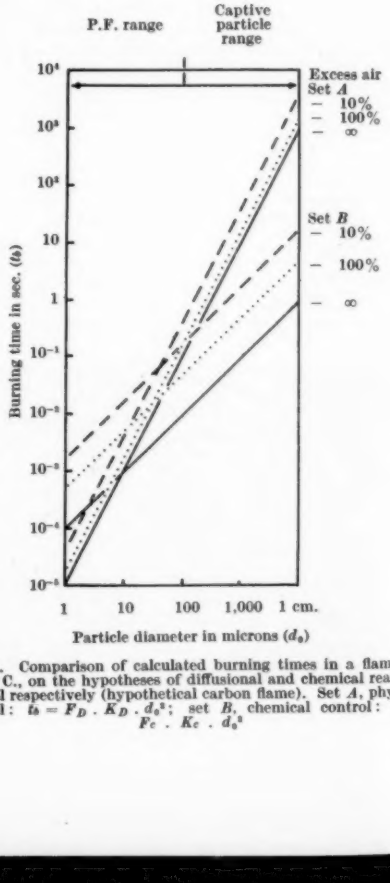

Fig. 1. Comparison of calculated burning times in a flame, at 1,500° C., on the hypotheses of diffusional and chemical reaction control respectively (hypothetical carbon flame). Set A, physical control: $t_b = F_D \, . \, K_D \, . \, d_0^2$; set B, chemical control: $t_b = F_c \, . \, K_c \, . \, d_0^2$

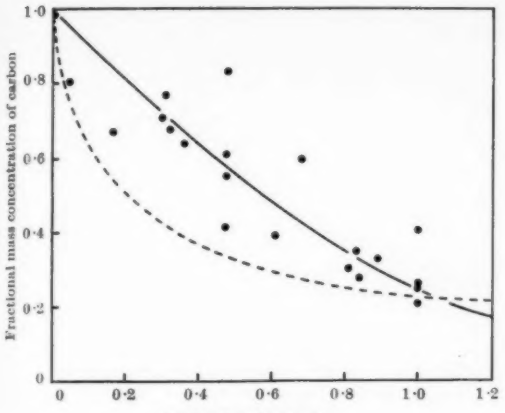

Fig. 2. Decay of carbon concentration in a dust flame with time. Comparison of experimental values (●) with predicted values assuming: (i) diffusional rate-control (dotted line); (ii) chemical rate-control (full line)

calculated[9e], and Fig. 1 shows the burning times predicted from the two theories for a carbon dust flame at 1,500° C. at three levels of excess air: 10 per cent, 100 per cent and infinity (single particle). From this it is clear that, if the assumptions made are valid, we have two regimes as follows: (1) the 'captive particle' range of 100 microns to 1 cm., over which the diffusional processes have been proved to be dominant when the convection field is weak; and (ii) the pulverized fuel range of 1–100 microns, inside which, in real flames (less than 100 per cent excess air), the diffusion mechanism is unimportant.

The existence of the first regime in weak convection fields is now established; its continued existence in strong convection fields is at present under experimental examination. The question immediately at issue here is: Does the first regime extend also into the pulverized fuel range, or is it superseded by the second regime, as suggested by argument from Fig. 1? To test this, predictions have been made from the alternative theories derived as special cases of a general theory (Siddall, R. G., private communication) and these have been compared with measurements from the furnace. The starting equations used were in effect (1*a*) and (1*b*), but integrated to predict the time required to burn to varying degrees of incomplete combustion, the effect of distribution of particle size being allowed for in this. The results of these calculations are shown in Fig. 2. In this, fractional mass concentration has been plotted against time for (i) diffusional control (dotted line), and (ii) chemical control (full line); the final fit was adjusted by means of a somewhat arbitrary constant the value of which is difficult to calculate from absolute theory, but the shapes of these curves are determined by the diameter function which is predicted. For the experimental comparison, the full circles are the experimental points.

In our opinion, the chemical control theory gives a much better fit to the experimental results than does the physical control theory. While, therefore, this is not yet conclusive, we suggest that surface reaction at high temperatures plays a much bigger part than previously imagined, and it therefore deserves much greater attention than has been accorded to it in the past.

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OCEANOGRAPHY

Alleged Occurrence of the Perchlorate Ion in Sea-Water

In a recent communication, Baas Becking, Haldane and Izard[1] claimed to have found up to 100 p.p.m. of perchlorate in sea and ocean waters, and between 100 and 1,000 p.p.m. in estuarine and inshore waters. They have suggested that this perchlorate is formed from chloride in the water by oxidation, and that the formation of perchlorate in this manner will reduce the chlorinity of the water to the extent of up to the second decimal per mille.

In view of this suggestion, we have re-investigated the occurrence of perchlorate in sea-water, using a new analytical method. The water sample is treated with potassium perrhenate and tetraphenylarsonium chloride; the precipitate of the slightly soluble tetraphenylarsonium perrhenate co-precipitates perchlorate from the sample. The dried precipitate is formed into a disk with potassium bromide and the amount of perchlorate is determined by measuring the optical density of the disk at 9·12μ. The method is sensitive to about 0·03 p.p.m. of perchlorate ion and has a coefficient of variation of about 9 per cent with 1·0 p.p.m. perchlorate ion. Neither periodate nor the ions normally present in sea water interfere.

We have examined surface and deep-water samples from 25 stations in the Arctic Ocean, North Atlantic, English Channel, Mediterranean, Indian Ocean, Red Sea and Persian Gulf. In no case have we been able to detect any trace of perchlorate. These negative results are confirmed by the observations of Klemperer[2] that the addition of as little as 0·05 p.p.m. of perchlorate to sea water reduces the rate of uptake of iodine by *Fucus ceranoides* by about 60 per cent.

It is suggested that the results obtained by Baas Becking *et al.*, using methods based on methylene blue, were in error owing to the interfering effects of many other ions, particularly sulphate[3] and chloride, and to the generally capricious nature of this reagent.

We thank Mr. J. Berkeley for making the infrared measurements.

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CHEMISTRY

Covalent Super-Exchange in Solid State Physics

Magnetic coupling of next-to-nearest neighbours through a non-magnetic anion (super-exchange) has been explained by Anderson[1] by considering 'excited states' in which a single electron in a *p*-orbital of the anion is transferred to one of the neighbouring cations. Goodenough and Loeb[2] have emphasized correctly that such interactions are essentially covalent and have given the name 'semi-covalence' to Anderson's one-electron transfer. As stressed by Goodenough and Loeb, the increase in Curie or Néel temperatures in series such as MnO-FeO-CoO-NiO, or MnO-MnS-MnSe-MnTe, is evidence for the part played by covalence in magnetic coupling.

Anderson's theory leads to the prediction that super-exchange should be antiferromagnetic if the paramagnetic ion has its original *d*-shell half-full or more (manganese, iron, cobalt, nickel, copper) and ferromagnetic otherwise (titanium, vanadium, chromium). There are many exceptions to this rule, as shown in Table 1.

Table 1. Ferromagnetic and Antiferromagnetic Compounds of Elements in First Transition Series

	Ti	V	Cr	Mn	Fe	Co	Ni	Cu
*M*O	*A*(8)	*A*(8)		*A*(10)	*A*(10)	*A*(10)	*A*(10)	*A*
M_2O_3	*A*(8)	*A*(8)	*A*(8½)	*A*(10)	*A*(10)			
MO_2		*A*(8½)	*F*(9)	*A*(9½)				
*M*S		*A*(8)	*F*(9)	*A*(10)	*A*(10)	*A*(10)	*A*(10)	*A*(10)
MS_2*				*F*(7)		*F*(7)	*F*(7)	
*M*Se		*A*(8)		*A*(10)				
*M*Te			*F*(9)	*A*(10)				
*M*As				*F*(9)				
*M*Sb			*A*(8)	*F*(9)				
*M*Bi				*F*(9)				

A, Antiferromagnetic; *F*, ferromagnetic; (*n*), number of electrons in covalent structure.
* Only electrons in *M*-S bonds counted.

Numbers in parentheses in Table 1 refer to the number of electrons participating in covalent bonding; that is, the number of electrons in molecular orbitals surrounding an anion. Inspection of these numbers indicates that antiferromagnetism tends to occur when n is even, whereas ferromagnetic coupling occurs when n is odd.

To determine the number n, one must first consider the effect of crystal-field splitting on the 3*d*-levels of the paramagnetic cation. Let n' be the number of electrons in the upper level (for example, 2 for manganese ions, 1 for chromium ions (Cr^{3+}), in an octahedral field). If p is the co-ordination number of the cation and q that of the anion, $n = n'\frac{q}{p} + n''$, where n'' is the number of valence electrons of the anion. It makes no difference whether n'' includes *s*-electrons or not, as the number of *s*-electrons is even. Thus for manganese sulphide, $p = q = 6$, $n' = 2$, $n'' = 8$ (or 6), $n = 10$ (or 8) and is even. In chromium sulphide (CrS), $n' = 1$, $n = 9$ (or 7) and is odd. Expressed in a different manner, n' is the number of 3*d*-electrons of the cation participating in the formation of hybrid orbitals, the nature of the latter being deduced from the symmetry of the anionic arrangement around a cation (for example, d^2sp^3 in octahedral manganese sulphide, d^2p^3 in the distorted trigonal antiprism of α-Fe_2O_3).

Although no rigorous treatment can be carried out at this moment, a simple argument may suggest why the sign of super-exchange interaction depends on whether n is even or odd. Consider manganese sulphide, in which both cation and anion are in octahedral co-ordination. Both can use d^2sp^3 hybrid orbitals, and six bonding and six antibonding molecular orbitals can be formed around each sulphur. These orbitals contain 10 electrons, and so with respect to a fully covalent structure the compound is deficient in electrons. Four molecular orbitals will carry two electrons each; charge correlation requires that the two remaining electrons be as far apart as possible, that is, 180°. These will go into molecular orbitals on opposite sides of the anion, thus accounting for the large angle characteristic of super-exchange. These two molecular orbitals are not fully orthogonal because of overlap of the orbitals of the cation on either side of the central anion, and they may thus be considered to form two orthogonal three-centred orbitals of slightly different energies. The ground-state will be such that the two electrons in the bridge occupy the lowest of the 3-centre orbitals with spins antiparallel; these electrons in turn interact with the remaining t_{2g} electrons on the adjacent cations (as implied in ionic-covalent resonance), which will be coupled antiferromagnetically. The single electron in the 3-centre orbital of chromium sulphide must lead to ferromagnetic coupling.

A similar analysis can be carried out for other substances listed in Table 1. More complicated oxides (for example, ferrites) present an additional problem in that n is commonly not an integer (9·75 in Fe_3O_4). For fractional numbers between 9 and 10, one may hesitate to predict the sign of super-exchange; possibly in such cases a small amount of direct exchange between next neighbours is the determining factor. For example, chromium oxide (Cr_2O_3) is antiferromagnetic although it might be expected to be ferromagnetic ($n = 8\frac{2}{3}$). Neutron diffraction reveals ferromagnetic coupling between cations at large distances and at large Cr-O-Cr angles; only interactions at shorter distances and through smaller angles (hence presumably not super-exchange) are antiferromagnetic. In dioxides with the rutile structure (vanadium, chromium, manganese dioxides), further complications arise from the possibility of extensive π-interaction between oxygen p (the oxygen is in trigonal planar hybridization) and metal t_{2g} orbitals. It is worth noting that the present arguments predict that a solid solution of vanadium oxide (VO_2) and manganese dioxide in the ratio 1 : 1 would have the same electron number as ferromagnetic chromium oxide, and should accordingly also be ferromagnetic, although the two end-members are both antiferromagnetic.

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Atomic Absorption Spectrophotometric Determination of Molybdenum and Strontium

RECENT work reported by Menzies[1] and Robinson[2] has suggested that atomic absorption flame methods[3,4] are not applicable to the determination of molybdenum and that the limit of strontium determination lies between 2 and 10 p.p.m. in solution.

Using a 10-cm. air-acetylene burner, a scale expansion device (suggested by Dr. J. B. Willis) and a modulated single-beam system[5], it has been found that the limits of estimation of molybdenum and strontium in solutions free from interfering ions are about 0·5 and 0·05 p.p.m. respectively. Molybdenum 3132 Å. (a^7S–y^7P^0) was the strongest in absorption of the nine absorbing molybdenum lines found. Strontium measurements were carried out on strontium 4607 Å. The gain in sensitivity for strontium over those previously reported is a direct result of stability of hollow cathode emission, the use of a long burner and the use of an expanded scale on the measuring unit reading 0–20 per cent absorption over full scale. The determination of molybdenum was achieved by adjustment of the air and acetylene pressures to give reducing conditions in the flame and passage of the beam from the hollow cathode discharge tube through the flame at a point just above the cone of unburnt gases.

The concentration of free ground-state atoms of molybdenum in the flame was found to be critically dependent on the proportions of air and acetylene. No perceptible absorption resulted from spraying a 50 p.p.m. molybdenum (ammonium molybdate) solution into an air-rich flame, whereas adjustment of the proportion of air to acetylene to give a flame in which yellowing due to incandescent carbon particles was just visible at the base gave an absorption of 35 per cent. Provided that the beam from the hollow cathode tube was confined to the lowest possible level in the flame, no great gain in sensitivity resulted from the use of a highly luminous flame. Despite this dependence on reducing conditions, the presence of an oxidizing agent in the sample solution did not cause serious depression of molybdenum absorption (compare cols. 3 and 4, Table 1). The presence of the large excesses of extraneous elements in the samples examined had a greater effect than did nitric acid (compare cols. 4 and 5, Table 1), but this effect was not so great as to cause difficulty in analysis due to loss of sensitivity.

The results in column 5 of Table 1 were obtained by use of the 'addition' method. This procedure has been used in arc emission determination[6,7] of trace elements in samples of widely variable major element composition. However, poor precision and uncertainty regarding linearity of the relationship between emitted intensity and concentration impairs its value in arc analysis. Provided the equation of a non-linear curve is known, the use of the addition method is possible, but tedious.

By taking three equal aliquots of a sample solution, adding equal volumes of water to one and solutions containing known concentrations of the analysis element to the other two, then analysing all three using the apparatus described, it was found that the relationship between percentage absorption and concentration was linear up to about 15 per cent absorption. This test has been carried out for molybdenum in the samples cited in Table 1, for strontium in ammonium chloride extracts of soils and in nitric–perchloric–sulphuric acid digests of plant material and for calcium in solutions for microbiological culture.

The addition method was found essential to the analysis of plants for strontium because measurements on synthetically prepared solutions indicated that the interferences would be so difficult to control that the results of analysis against orthodox standards would be unreliable. Advantage may be gained from the general application of the addition method to atomic absorption analysis because, in using it, both sample and 'standard' are measured under exactly the same conditions of viscosity, surface tension and chemical interference and because modulated atomic absorption apparatus cannot measure anything but atoms of the analysis element in the flame.

Although insufficient sensitivity has been attained, as yet, in the direct atomic absorption analysis of solutions from plants and soils for molybdenum, the results in Table 1 indicate that advantages can be gained from its application to such analytical fields as those of the fertilizer and metallurgical industries. The specificity of the atomic absorption method employing a modulated system for measurement of the element sought gives it obvious advantages over flame emission methods in the analysis of soils, plants, bones and the like for natural strontium in 'fall-out' studies.

The results for molybdenum suggest the possibility of using reducing flame conditions to make possible atomic absorption analysis for other elements. They also suggest that further gains in sensitivity may result not only from designing burners to give high-temperature flames, but also from designing them to produce highly reducing conditions in the flame.

The apparatus used and the results of these and further investigations will be described in detail elsewhere.

Table 1. Concentrations of molybdenum in samples of molybdenized superphosphate (nominally 1·5 oz. molybdenum trioxide per cwt.) and stainless steel as calculated from atomic absorption analysis against standards in water, in 0·32 *N* nitric acid and by the 'addition' method. The analyses were carried out directly on portions of 200-ml. final volumes of nitric–hydrochloric acid solutions prepared from the samples

Sample	Weight taken (gm.)	Apparent molybdenum concentration using Standards in water (per cent)	Standards in nitric acid (per cent)	Molybdenum concentration by addition method (per cent)
Superphosphate (1)	8·42	0·0317	0·0356	0·0575
(2)	10·0	0·0366	0·0412	0·0555
(3)	10·0	0·0366	0·0412	0·0526
Stainless steel (1)	2·930	0·159	0·179	0·266
(2)	2·933	0·171	0·192	0·278

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Determination of Nickel and Cobalt by Atomic Absorption

In the atomic absorption method of analysis, first described by Walsh[1], the solution to be analysed is sprayed into a flame, and with a hollow-cathode lamp which emits the line spectrum of the element being determined as the light source, the absorption of light by atoms of the element is measured at a characteristic wave-length.

To realize the full potentialities of the method, it is obviously important that the strongest absorption line be used. As at the temperature of commonly used flames all but a small proportion of the atoms are in the ground-state, only lines due to absorption by unexcited atoms need be considered, and of these lines it is usually assumed that the strongest absorption line will correspond to the strongest emission line. I have pointed out that while this is so in the simple spectra of the elements in Groups I and II, it is not necessarily the case in the more complex spectra of the heavier elements, and that as oscillator strengths for the various lines of these elements are generally not known, it is necessary to determine experimentally which line is the strongest in absorption[2]. Results were given for manganese and iron, showing that for these elements the strongest absorption lines were at 2794·8 Å. and 2483·3 Å. respectively.

The spectra of nickel and cobalt have now been investigated by the methods described previously. It has been found that the strongest absorption line for nickel is at 2320·0 Å. ($a^3F_4 - y^3G^o_5$), the absorption at this wave-length being about fifteen times that at 3415 Å., the wave-length of the strongest emission line. For cobalt, the strongest absorption line is at 2407·2 Å. ($a^4F_{4\frac{1}{2}} - x^4G^o_{3\frac{1}{2}}$), and this line is about fifty times as sensitive in absorption as is the strongest emission line at 3527 Å.

When these lines are used, the atomic absorption method can usefully be applied to the determination of nickel and cobalt, the sensitivity obtained being about the same as that already reported for iron.

I thank Mr. O. E. Clinton for his assistance with this work, full details of which will be reported elsewhere.

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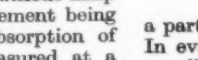
BIOCHEMISTRY

Steric Factors affecting the Specificity of Polyglycosidases

The marked substrate specificity exhibited by enzymes has been related to a steric affinity between the molecule attacked and the attacking enzyme[1]. According to this concept, proper orientation of the substrate in the vicinity of the enzyme permits formation of an activated intermediate in which several points of contact may be established.

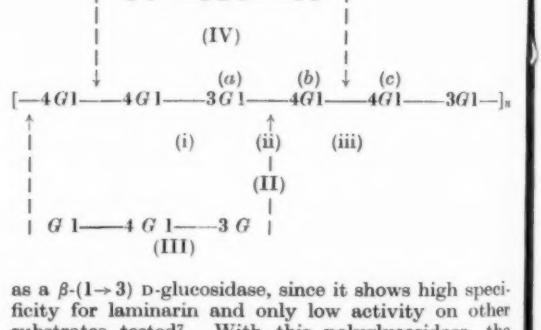
Enzymes which hydrolyse simple glycosides exhibit extremely high specificity for the glycosyl radical of the molecule, whereas the structure of the aglycone group usually is important in a quantitative, rather than qualitative, sense[2,3]. Glycosidases that degrade polysaccharides (I) appear to show high specificity for



(I)

a particular type of linkage, as well as glycosyl unit. In evaluating such specificity, the enzyme is tested usually with several polysaccharides each of which contains only one type of sugar component and linkage (or as close as possible to this ideal); this procedure has become general since few polysaccharides of more complex structure are characterized in sufficient detail to be suitable as enzyme substrates. Cellulase, for example, degrades polymeric chains in which β-D-glucopyranose units are linked through positions-1 and -4 (I, G = D-glucopyranosyl; $X = 4$) but not when the linkages are β-(1→3), α-(1→4), etc., and is regarded as a β-(1→4)-poly-D-glucopyranosidase. In common usage, this terminology refers to the linkage cleaved, and implies that its position of attachment to unit I(*b*) has an important bearing on specificity. However, the glycosyl unit (*a*) is itself attached to a third unit (through the X-hydroxyl group), and the location of this linkage also might be expected to affect specificity through its influence on the stereochemistry of (*a*). Clearly, the relative importance of these steric factors is difficult to assess with polysaccharides of homogeneous structure. Recent observations[4] on the enzymolysis of a polysaccharide that contains mixed types of linkages suggest, however, that such questions should be taken into account in classifying polyglycosidases.

The polysaccharide examined is a soluble D-glucan from oats[5,6], the structure of which is represented[4,6] mainly by II, that is, a linear chain of β-D-glucopyranosyl units in which two (1→4) linkages (ii) and (iii) alternate repeatedly with a (1→3) linkage (i). Two different enzyme preparations have been found to degrade the glucan rapidly and extensively under conditions expected to minimize trans-glycosidation side-reactions. One of the enzymes has been classified



as a β-(1→3) D-glucosidase, since it shows high specificity for laminarin and only low activity on other substrates tested[7]. With this polyglycosidase, the major product obtained from the oat glucan is trisaccharide III[4,6], showing clearly that hydrolysis is preferential for linkage (ii), that is, the glycosidic bond of a β-D-glycosyl unit (*a*) attached through positions-1 and -3 to adjacent units, rather than a β-(1→3) linkage (i). (In laminarin, of course, most of the glycosyl units possess this type of 1,3-relationship.)

The second enzyme used, a cellulase from *Streptomyces* sp. *QM B814*[8], degrades the glucan mainly to trisaccharide IV[4,6], showing that the hydrolytic action

of this enzyme is preferential for linkage (iii). Now, linkages (ii) and (iii) of the polysaccharide are both of the β-(1→4) type, but glucosyl unit (*a*) is substituted at position-3; glucosyl unit (*c*) is substituted at position-4 but is attached to position-3 of an adjacent unit. Hence only glucosyl unit (*b*) is equivalent to a unit in a cellulose chain. The ready attack by the *Streptomyces* cellulase at this point indicates that the → 4-β-D-glucose relationship is at least as important for the enzyme action as is the β-D-glucose-(1→4) relationship.

These considerations are subject, of course, to the usual qualification that the enzymes used may not be pure—a difficulty which at present cannot be settled. However, they direct attention to the possibility that the current view of polyglycosidase stereospecificity is insufficiently broad. It may thus be desirable to regard cellulases, for example, as exhibiting (4→)-β-(1→4)-D-glucopyranosidase activity in recognition of the fact that the substrate attacked contains a 4-*substituted* β-D-glucopyranosyl unit, and not a free β-D-glucopyranosyl unit. Such a term would be particularly apt for several known cellulases that degrade cellulose but do not attack cellobiose. The latter, it will be noted, contains the β-(1→4) linkage but the glycosyl unit itself is not substituted at position-4. Similar considerations could apply for other polyglycosidases (for example, β-amylases) that produce oligosaccharides, but not monomer, from polysaccharides.

We are grateful to Dr. E. T. Reese for permission to quote unpublished data from collaborative studies.

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'pH-Chromatography' of some Amphoteric Antibiotics

'*p*H-CHROMATOGRAPHY' is a paper chromatography method which can be used for simultaneous determination of the ionic character of antibiotics and of suitable *p*H values for their extraction[1]. The *p*H-chromatogram of an antibiotic is obtained by chromatographing on a series of strips of chromatographic papers buffered to *p*H values from 2 to 10. For the development of the strips by the ascending technique an organic solvent saturated with water is used. A suitable solvent is chosen by determining the solubility of the antibiotic being studied by paper chromatography[2]. In our reports on the *p*H-chromatography of antibiotics[1,3] we described three types of *p*H-chromatograms, depending on the ionic character of antibiotics:

(1) R_F values of *p*H-chromatograms of antibiotics of acidic nature give *S*-shaped curves, the maxima of which lie in the acidic range; with increasing *p*H values the R_F values diminish.

(2) The R_F values of *p*H-chromatograms of antibiotics of basic character give S-shaped curves of a reverse character; the maximum of the curves being in the basic and the minimum in the acidic range, respectively.

(3) *p*H-chromatograms of neutral antibiotics have practically the same R_F values along the whole range of *p*H values, giving a straight line parallel with the starting points.

The optimal *p*H for extraction of acidic or basic antibiotics is in the region of the maximal R_F value; the most suitable *p*H for re-extraction into water being that *p*H where the R_F on the *p*H-chromatogram is smallest.

We use *p*H-chromatography in seeking new antibiotics and sometimes obtain *p*H-chromatograms of a different type, which have so far not been described. The R_F values of this type of *p*H-chromatogram increase stepwise in the range of lower *p*H values and after reaching a certain maximum they begin to diminish. These compounds behave as bases from *p*H 2 to the point of their maximal R_F, and from this point on up to *p*H 10 they behave as acids. We presume that compounds belonging to this group are amphoteric.

We have run *p*H-chromatograms of some known amphoteric antibiotics, chlortetracycline, oxytetracycline, tetracycline, and mycostatin (nystatin) to verify this. The *p*H-chromatography of all these antibiotics was performed by the ascending technique in *n*-butanol saturated with water, the spots being detected microbiologically.

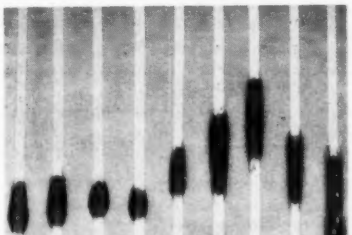

Fig. 1. *p*H-chromatogram of tetracycline in *n*-butanol saturated with water

In Fig. 1 a *p*H-chromatogram of tetracycline is presented. The R_F values of the spots increase stepwise up to *p*H 8, and successively diminish in the region of higher *p*H values.

The dependence of the R_F values of tetracyclines on *p*H values is depicted in Fig. 2. The R_F curves of chlortetracycline and tetracycline have a similar character and the maxima of both lie in the region of *p*H 8. The maximum of the R_F curve of oxytetracycline is in the region of *p*H 6, and the character of this curve is different from the character of the curves of previously mentioned antibiotics. We presume that the character of the curves is to some degree a function of the structure of the compounds studied, chiefly of the number of 'acidic' OH-groups present, chlortetracycline and tetracycline having five, and oxytetracycline six, OH-groups, respectively.

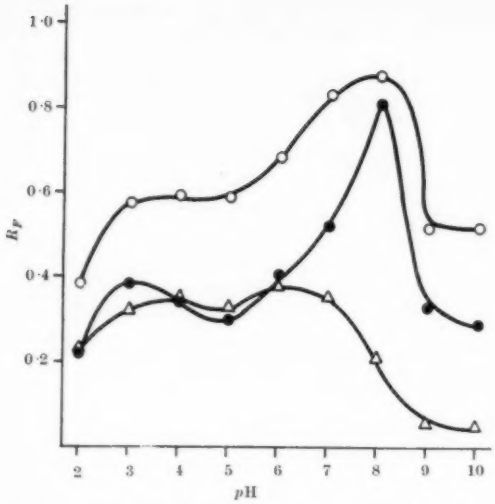

Fig. 2. Dependence of the R_F of tetracyclines on pH; solvent: *n*-butanol saturated with water. ○, Chlortetracycline; △, oxytetracycline; ●, tetracycline

In Fig. 3 the dependence of the R_F values of mycostatin on pH is shown; the curve having its maximum in the region of pH 8.

In all the cases presented the curves are not absolutely smooth; for example, they do not have the smooth character of the curves of acidic and basic antibiotics. Up to now we do not know the cause of this phenomenon; but we presume it could be caused by different chemical structure of the compounds studied.

We have also analysed by pH-chromatography the antibiotic *cyclo*serine (oxamycin), the data of the ionic character of which differ in the literature. According to Harned *et al.*[4] this compound is a weak acid, whereas others[5] consider this compound to be amphoteric. The pH-chromatogram of this antibiotic (Fig. 4) proves it to be amphoteric.

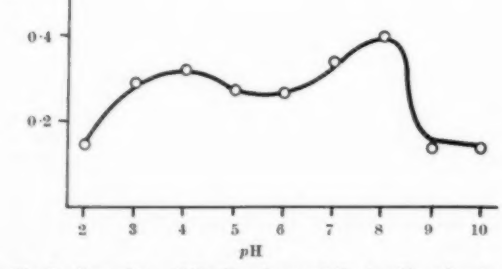

Fig. 3. Dependence of the R_F of mycostatin on pH; solvent: *n*-butanol saturated with water

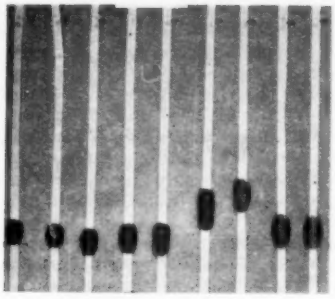

Fig. 4. pH-chromatogram of *cyclo*serine in methanol

By the method described here, unidentified and, up to now, not even concentrated antibiotics can be divided into four groups according to their ionic character, that is, into acids, basic, neutral, and amphoteric compounds, and the suitable pH values for their extraction and eventual re-extraction into water can be determined. As the optimal pH value for the extraction of acidic and basic antibiotics lies in the range of that pH value where the R_F on the pH-chromatogram is greatest[1], we can presume that the same would be valid also for amphoteric antibiotics. Similarly, the region of the smallest R_F values indicates the most suitable pH for the re-extraction from the organic solvent into water.

We are of the opinion that the pH-chromatographic method can be used also for the determination of the ionic character of other compounds of biological origin and for the determination of suitable isolation procedures of these compounds.

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Interaction of Actinomycin with Deoxyribonucleic Acid

In previous papers, Kawamata *et al.*[1,2] have reported the carcinogenic effect of actinomycin. In the course of investigating the mechanisms of action of actinomycin, evidence was obtained that this antibiotic shows a specific interaction with deoxyribonucleic acid. In the following experiments actinomycin *S* was used[3].

In order to examine the relation between nucleic acids of bacteria and actinomycin *S*, the extracts obtained from bacteria cultured in the presence or absence of actinomycin *S* were subjected to zone electrophoresis.

Bacillus subtilis strain NRRL-*B*558 was grown on a salt–glucose plus casein acid hydrolysate medium by shaking at 35° C. After culture for 6 hr. 10 μgm. of actinomycin *S* was added to the culture medium and incubated further for 1 hr. Then the bacteria were harvested and washed twice with chilled, distilled

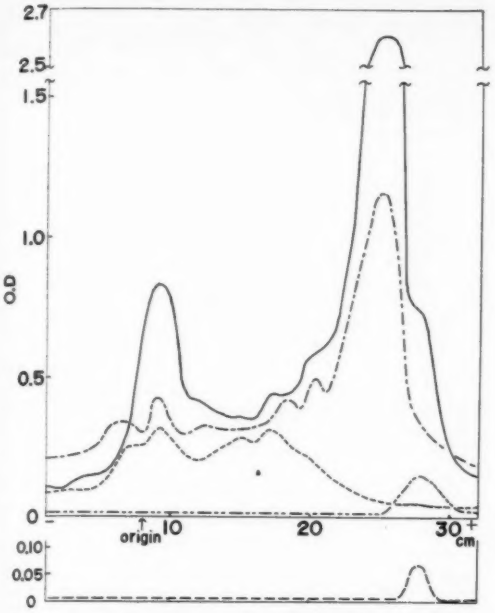

Fig. 1 Starch electrophoresis patterns of an extract of *B. subtilis*. Bacteria were grown at 35° C. with shaking in salt–glucose plus amino-acid medium. 10 μgm./ml. actinomycin *S* was added after 6-hr. culture. (———), ultra-violet absorption at 260 mμ; (– – – – –), Folin's reaction at 750 mμ, (— — — —), orcinol–hydrochloric acid reaction at 660 mμ, (— – — – —), diphenylamine reaction at 600 mμ, (— — — —), spectral absorption of actinomycin *S* at 440 mμ

water and an extract was prepared in 0·1 *M* phosphate buffer solution by grinding the precipitate of bacteria with alumina. Starch electrophoresis was performed in *p*H 8·3 borate buffer, ionic strength 0·1. The runs were made at 5° C. with constant current of 3 m.amp./cm.² for approximately 17 hr. The starch was then cut into 1 cm. sections, and each section was eluted with distilled water. The eluates were used for subsequent analyses. Total nucleic acid was estimated by readings of optical density at 260 mμ. The amounts of protein, ribonucleic acid and deoxyribonucleic acid were estimated by the Folin, orcinol, and diphenylamine methods respectively. Actinomycin *S* was estimated by readings of optical density at 440 mμ.

Results of analyses of a starch electrophoresis are shown in Fig. 1. Amounts of substances are plotted against distance travelled from the origin towards both electrodes. Actinomycin *S* was found to be distributed corresponding to the fraction of deoxyribonucleic acid. The same pattern was obtained when actinomycin *S* was subjected to zone electrophoresis together with the extract prepared from bacteria cultured in the absence of actinomycin *S*. Actinomycin *S* alone, however, travels to the cathode. Such an interaction was observed between actinomycin *S* and deoxyribonucleic acid prepared from calf thymus.

Table 1. Reversing Effect of Deoxyribonucleic Acid on Growth Inhibition of *B. subtilis* NRRL-*B*558 by Actinomycin *S*

Actinomycin *S* in medium (μgm./ml.)	Time incubated (hr.)	Turbidity E_{550}			
		Deoxyribonucleic acid of calf thymus		Ribonucleic acid of yeast	
		none	0·05%	none	0·05%
0	0	0·055	0·055	0·040	0·040
	2	0·075	0·072	0·072	0·080
	4	0·240	0·250	0·370	0·300
	6	0·570	0·560	0·700	0·720
	8	0·700	0·730	0·790	0·810
0·01	0	0·055	0·055	0·040	0·040
	2	0·060	0·075	0·055	0·082
	4	0·075	0·240	0·075	0·107
	6	0·085	0·560	0·080	0·120
	8	0·090	0·710	0·080	0·150

Moreover, the inhibition of bacterial growth by actinomycin *S* was virtually abolished in the presence of thymus deoxyribonucleic acid in the medium, but not of yeast ribonucleic acid. The results are shown in Table 1.

In considering the fact that actinomycin has a potent anti-cancer activity, as well as marked carcinogenic effect in mice, the interaction shown between actinomycin *S* and deoxyribonucleic acid might play an important part in the mechanism of action. The mode of this interaction is now under investigation.

It is hoped that a full account of this work will be published elsewhere.

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Biosynthesis of Sucrose by Preparations from Potatoes stored in the Cold and at Room Temperature

Perhaps the most pronounced and consistent metabolic response of potato tubers to stress situations, such as low and high temperatures, loss of water, and ionizing radiation, is the accumulation of sugars, especially sucrose. Although the relationship of sugar content to the so-called non-enzymatic browning of processed potato products has been amply documented[1], the biochemical events which create a milieu favourable to accumulation of sucrose are unknown. Conceivably, this increase in sucrose could arise as the result of changes in amounts of enzymes involved in sugar formation from starch, as compared with those involved in removal of sucrose.

Of these enzymes, the one most likely to be involved directly in sucrose metabolism would seem to be uridine diphosphoglucose → fructose-transglycosylase, first described by Leloir and co-workers[2] in wheat germ, maize germ, potato sprouts, pea seeds, beet shoots, etc., and demonstrated more recently in sugar beet leaves[3] and in soybeans and broad beans[4]. Although a net increase of sucrose has been demonstrated when fructose or glucose is administered to potato disks[5] and when potato tuber homogenates are incubated in the presence of glucose-1-phosphate, fructose, and dextran sucrase[6], demonstration of the presence of uridine diphosphoglucose → fructose-transglycosylase in potato tubers has not been reported.

We have now found that the potato tuber is a rich source of sucrose-synthesizing enzyme (Table 1). The enzyme fractions were prepared from 600 gm. of peeled Washington Russet tubers

previously stored for 12 days at 25° C. or 2° C. The tubers were homogenized with 30 ml. of 0·1 *M* phosphate buffer of *p*H 7·0. After filtration through 'Celite', the filtrate was made 0·7 saturated with respect to ammonium sulphate. The precipitate was collected by filtration and dialysed against cold distilled water. The dialysed preparation (retentate) was centrifuged and the supernatant discarded after assays showed that it contained only minimal activity as regards synthesis of sucrose.

The precipitate obtained from dialysis of the preparation from potatoes stored at 25° C. was suspended in 62 ml. of water. By analysis, each millilitre had 1·97 mgm. of protein nitrogen and was equivalent to 9·7 gm. of fresh potato tissue. Corresponding values for the enzyme preparation from potatoes stored at 2° C. were 65 ml. total volume, 1·73 mgm. protein nitrogen per ml., and each millilitre of enzyme represented 9·2 gm. of fresh potato tissue. Sucrose was determined by the method of Rorem *et al.*[3], in which the residual colour and reducing sugars are eliminated by the addition of sodium borohydride prior to development of colour with resorcinol. The formation of sucrose in the enzyme reaction mixture was also demonstrated by paper chromatography.

The rates of synthesis of sucrose compare favourably with those of crude preparations from other plant sources. No significantly great differences were observed between the enzymatic activity of the protein fraction from tubers stored at 2° C., in which sucrose accumulates, and that from tubers stored at 25° C., in which sucrose does not accumulate. Both preparations exhibit the same apparent *p*H optimum for synthesis of sucrose and both possess invertase activity. The *p*H optimum for sucrose synthesis (Table 1) is probably not the true *p*H optimum of the enzyme, since at *p*H 8·1 we found that the invertase activity drops off rather sharply from that found at *p*H 7·1, thus allowing more sucrose to accumulate at the higher *p*H. It will be noted that the presence of invertase in the preparation from potatoes stored in the cold resulted in a decrease in sucrose in the enzyme reaction mixture at *p*H 7·1 after prolonged incubation. The presence of invertase in these preparations also vitiated attempts to establish the equilibrium of the reaction.

Additional experiments showed that these potato preparations can synthesize sucrose or sucrose-phosphate when fructose-6-phosphate is substituted for fructose in the enzyme reaction mixture. The possibility of conversion of the fructose-6-phosphate to free fructose by a phosphatase, however, has not been completely eliminated.

In two sets of experiments, enzyme preparations from the White Rose variety, known to be a good sugar former, synthesized sucrose at a rate 3–4 times as great as similar preparations from Washington Russet. These preliminary experiments suggest that varieties which tend to accumulate large amounts of sugar contain more enzyme than those with smaller accumulation of sugar.

Table 1. Micromoles of Sucrose synthesized by Enzyme Preparations from Washington Russet Variety Potato Tubers

*p*H	Enzyme from tubers stored at 25° C.			Enzyme from tubers stored at 2° C.		
	Incubation time			Incubation time		
	1 hr.	2 hr.	4 hr.	1 hr.	2 hr.	4 hr.
7·1	0·155	0·193	0·232	0·085	0·096	0·047
7·5	—	0·284	—	—	0·272	—
7·8	—	—	—	—	0·425	—
8·1	—	0·376	—	—	0·471	—
8·4	—	0·290	—	—	0·460	—

The enzyme reaction mixtures containing 3 micromoles uridine diphosphoglucose, 8 micromoles fructose, 0·002 ml. of 0·1 *M* magnesium chloride, 0·04 ml. of 1 *M tris* buffer and 0·68 ml. of enzyme in a total volume of 0·8 ml. were incubated at 37° C.

These results appear to eliminate the possibility of induced uridine diphosphoglucose → fructose-transglycosylase formation in response to the altered environment as a factor in the accumulation of sucrose in potato tubers stored at low temperatures. The absence of radical changes induced by temperature in content of other enzymes involved in carbohydrate metabolism of potatoes, namely, phosphatase and amylase[5], and phosphorylase[7], suggests alternate mechanisms of enzyme control or control at less purely biochemical levels.

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Optimal Protein Synthesis by Ascites Tumour Cells *in Vitro*

Warburg and Hiepler[1] have stated that ascites tumour cells show the highest metabolic rates when incubated in their own ascitic fluid. Littlefield and Keller[2] later showed that the incorporation of ^{14}C-amino-acids into mouse ascites cell proteins occurs at a rapid rate when the whole ascitic fluid is fortified with glucose and buffer salts and incubated in air. Incorporation is considerably greater than when buffer salts alone are used. More recently, Quastel, Bickis and Vas[3] reported that the sera of many different species of animals (rat, mouse, rabbit, guinea pig, ox) stimulate the incorporation of ^{14}C-glycine into the proteins of washed intact Ehrlich mouse ascites cells *in vitro*, in some cases by as much as fivefold. This stimulation of incorporation was also shown by the mouse ascitic fluid and by heated serum ultra-filtrates. The stimulation of incorporation of amino-acids into these cells by rat serum has now been investigated in greater detail and found to be due to the combined effects of glucose, glutamine, bicarbonate and amino-acids. These substances, used in the same concentrations as are found in the serum, can replace the serum fully (see Table 1).

Since the incorporations of different amino-acids were not stimulated to the same extent by rat serum under identical conditions (for example, glycine by 187 per cent, valine by 133 per cent, leucine and glutamic acid by less than 10 per cent), great care was taken to show that the stimulated incorporation occurred via the normal pathways for protein synthesis. Glycine incorporation was studied in detail in this respect. Techniques were employed

Table 1. INCORPORATION OF ^{14}C-GLYCINE INTO ASCITES CELL PROTEINS IN THE ABSENCE AND PRESENCE OF RAT SERUM AND SYNTHETIC SERUM MIXTURES

Additions	Specific activity of isolated protein (c.p.m./mgm.)	Activity relative to control
None (control)	41	1·00
0·28 m*M* glucose	69	1·68
0·66 m*M* glutamine	86	2·10
2·6 m*M* bicarbonate ($NaHCO_3$)	31	0·75
2·6 m*M* bicarbonate + 0·66 m*M* glutamine	96	2·34
0·28 m*M* glucose + 2·6 m*M* bicarbonate + 0·66 m*M* glutamine	104	2·54
0·28 m*M* glucose + 2·6 m*M* bicarbonate + 0·66 m*M* glutamine + amino-acids (0·5–45 μM) (ref. 5)	144	3·51
Rat serum (0·3 ml.)	106	2·59
Rat serum + glucose + bicarbonate + glutamine (as above)	121	2·95
Rat serum + glucose + bicarbonate + glutamine + amino-acids (ref. 5) (as above)	124	3·02

Each incubation mixture contained 3·0 ml. (total volume) of a 3·3 per cent suspension of washed ascites cells (wet weight) in Krebs–Ringer phosphate buffer, *p*H 7·4. The initial concentrations of added glucose, bicarbonate and amino-acids are given and are equivalent to the addition of 0·3 ml. serum. The glutamine added was, in this case, equivalent to 3·0 ml. serum. The final concentration of glycine was 2·0 m*M* and contained 10^5 c.p.m. radioactivity.

in the isolation of 'protein' free of nucleic acid and lipids that are known to minimize the non-peptide bonding of amino-acids to protein[4]. The final products, when subjected to controlled acid hydrolysis, released radioactivity from the protein isolated from cells incubated in the absence or presence of heated serum ultra-filtrate at the same rate. When the samples were subjected to exhaustive acid hydrolysis (16 hr. in 6 *N* hydrochloric acid at 110° C.) and the products examined by two-dimensional chromatography and radioautography, carbon-14 activity was found only in the areas corresponding to the positions in which glycine and serine are found. About 20 per cent of the total label appeared as serine in both cases. Unlabelled serine depressed the labelling of the tumour-cell proteins by ^{14}C-glycine either in the absence or presence of the heated serum ultra-filtrate to the same extent, indicating that the glycine–serine interconversion was unaffected by the serum factors. When protein was isolated from the different cell fractions separated by ultracentrifugation in the usual manner[2], the debris—nuclei, mitochondrial, microsomal, supernatant, fractions soluble and insoluble at *p*H 5, though labelled to different extents, showed the same proportional increases when the cells were incubated in the presence of heated serum ultra-filtrates.

It would thus appear that 'stimulated incorporation' is not fundamentally different from ordinary incorporation. Some other explanation must be invoked to account for the different responses of different amino-acids to the serum-factors. One possibility is that there are different levels of the various ^{14}C-amino-acids in the 'pool' synthesized from the added amino-acid, which are afterwards utilized for incorporation. It may be also that considerably higher concentrations of some amino-acids are required to produce optimal levels of activated amino-acids for incorporation.

The responses of the ascites cells to the various components of the synthetic serum mixture are quite interesting. When a maximal stimulation of incorporation of ^{14}C-glycine by heated serum ultra-filtrate of 200–240 per cent was observed, 68 per cent of the effect could be obtained with glucose in the same amount as found in the rat serum, 110 per cent by glutamine alone, 134 per cent by glutamine plus bicarbonate, but only 154 per cent by combining all three. When an amino-acid mixture was also added, equivalent to the amounts found in human serum[5], a final stimulation of 200–250 could be obtained. Thus it appears that glutamine is a major factor in the serum and, since the mouse ascitic fluid is lacking in glucose, glutamine is probably a major factor in ascitic fluid for the stimulated incorporation of amino-acids. This effect of glutamine is well known[6], and probably results from the fact that washed ascites cells are deficient in glutamine due to the presence of a high intracellular glutaminase activity. There is little effect of glucose in combination with the other serum factors, yet it stimulates glycine incorporation by 68 per cent on its own, indicating that an 'energy source' is needed for optimal incorporation in these systems. It seems likely that glutamine can act indirectly through the actions of glutaminase and transaminase as an 'energy source' also. In every case the washed cells were incubated in Krebs–Ringer phosphate buffer, *p*H 7·4. The effect of adding bicarbonate alone (final concentration only 1–2 m*M*) was to depress the incorporation of glycine by 25 per cent. However, if added when glutamine is present, the stimulation due to incorporation of glycine is even greater than with glutamine alone. These effects are difficult to explain.

In summary, it can be said that the effects of serum, and probably of ascitic fluid also, in stimulating the synthesis of protein in ascites cells, are probably due to the presence of substances which lead to the production of increased levels of the activated amino-acids required for higher rates of protein synthesis. This can occur by supplementing the cells with deficient amino-acids and with 'energy sources' which can give rise to higher levels of adenosine triphosphate.

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Effect of Heavy Water on Respiratory-chain Enzymes

DURING radiobiological work on bacteria it was found by one of us (H. L.) that the effect of ionizing radiation (X-rays) is greatly potentiated if the bacteria are irradiated in a medium in which water is replaced by heavy water[1]. Thus, for example, with *Escherichia coli B* and *Pseudomonas* 6009 the dose-reduction factor was approximately 2, that is, the X-ray dose required to produce a given reduction in the number of colony-forming bacteria on irradiation

in deuterium oxide was one half that in water. This effect, however, occurred only if the bacteria were irradiated in presence of oxygen, but not, or only insignificantly, after irradiation under anaerobic conditions.

Heavy water has for some time been known to affect a variety of chemical reactions and biological processes[2], the rates of which, as a rule, are slowed down.

In the present experiments the respiratory-rate of the bacteria used was decreased by approximately 45 per cent and that of baker's yeast by 75 per cent in 95–98 per cent deuterium oxide, as compared with water medium, the inhibition becoming apparent immediately at the beginning of the experiment. The rate of anaerobic fermentation of *E. coli*, on the other hand, was not affected by deuterium oxide for the first 2 hr. (An inhibition developed after 2 hr.)

Similarly the rate of aerobic succinate oxidation in the Keilin and Hartree heart-muscle preparation was increasingly inhibited with increasing concentrations of deuterium oxide, maximal inhibition being between 45 and 50 per cent in 99 per cent deuterium oxide, while the rate of anaerobic oxidation of succinate with methylene blue as hydrogen acceptor was not affected.

In order to gain further insight into the mechanism responsible for metabolic effects of deuterium oxide as manifested, for example, in inhibition of respiration in intact cells and of oxidations in isolated enzyme systems, further experiments have been undertaken.

Table 1. Effect of Deuterium Oxide on Respiratory-Chain Enzymes in Heart-Muscle Preparation

Enzyme activity	Inhibition (per cent) by 95–99 per cent deuterium oxide
Succinate-methylene blue	5
Succinate-ferricyanide*	26
Succinate-cytochrome *c*	37
Succinate-O_2	35
DPNH-methylene blue	3
DPNH-cytochrome *c*	34
DPNH-O_2	34
Cytochrome *c*-O_2	52

* In the presence of antimycin.
DPNH, reduced diphosphopyridine nucleotide.

The results given in Table 1 show that replacing the water in the medium by 90–99 per cent deuterium oxide inhibited the oxidation of succinate by oxygen, ferricytochrome *c* or ferricyanide, and the oxidation of reduced diphosphopyridine nucleotide by oxygen or ferricytochrome *c*, in the presence of heart-muscle preparation. The cytochrome *c* oxidase reaction was also inhibited (cf. ref. 3). On the other hand, oxidation of succinate or of reduced diphosphopyridine nucleotide by methylene blue with heart-muscle preparation was not appreciably inhibited.

Table 2. Effect of Deuterium Oxide on Rate of Oxidation of Succinate by Rat-Liver Mitochondria and on P : O Ratio (0·06 *M* Succinate)

Exp.	Activity of control		Inhibition (per cent) by deuterium oxide	
	Qo_2*	P : O	in absence of dinitrophenol	in presence of 3×10^{-5} *M* dinitrophenol
1	90	1·71	7	0
2	114	1·58	21	0
3	142	—	21	—
4	146	—	29	16
5	163	1·73	29	6
6	262	—	58	26

* μl. oxygen/mgm. protein/hr.

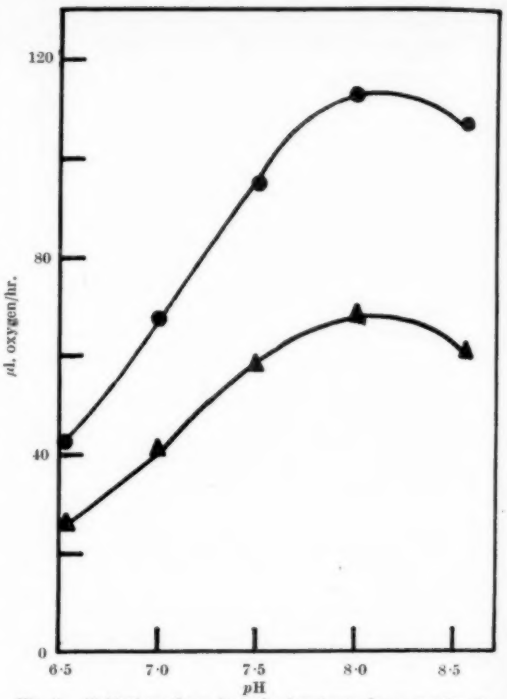

Fig. 1. Oxidation of succinate by heart-muscle preparation in (●) H_2O and (▲) D_2O medium as a function of *p*H

The inhibition of succinate oxidation catalysed by rat-liver mitochondria was variable, being greater with preparations having a higher activity (Table 2). The degree of inhibition was considerably decreased by the addition of 3×10^{-5} *M* dinitrophenol, which inhibited the rate of oxidation only slightly (7–34 per cent). Deuterium oxide decreased the P : O ratios only slightly, both in the presence and the absence of dinitrophenol.

The experiment described in Fig. 1 shows that replacement of water by deuterium oxide did not alter the *p*H optimum of the succinic oxidase activity of heart-muscle preparation and that the degree of inhibition was practically independent of *p*H (or *p*D) between 6·5 and 8·6. Thus the inhibition is not due to a possible difference in the degree of ionization of water or deuterium oxide or of the buffer in water and deuterium oxide.

The enzyme-catalysed reductions of methylene blue by reduced diphosphopyridine nucleotide and by succinate, which were not inhibited by deuterium oxide, represent probably a simple transfer of hydrogen atoms from substrate to methylene blue, catalysed by the respective dehydrogenases and intermediate carriers. These reactions are not accompanied by phosphorylation in mitochondrial preparations. However, those reactions which involve larger segments of the respiratory chain and which are associated with phosphorylation in mitochondrial preparations are inhibited by deuterium oxide in the non-phosphorylating heart-muscle preparations.

The inhibitions given in Tables 1 and 2 were determined immediately after adding the enzyme preparations to the reaction mixture. They cannot, therefore, be due to a possibly decreased reaction-

rate with deuterium-labelled substrate, formed by exchange reactions, since these are relatively slow[4] and could not become manifest at once.

We should like to suggest as explanation of these results that a protonolysis is a rate-limiting step of the respiratory chain in non-phosphorylating preparations, and that replacement of H^+ by the heavier D^+ slows down these reactions[2,3]. It seems particularly significant that the succinic oxidase of phosphorylating preparations is considerably less inhibited in the presence of dinitrophenol, which is believed to increase the rate of hydrolytic reactions[5].

As yet, however, no basis has been found for explaining the potentiation of radiation effects in deuterium oxide.

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Influence of Different Types of Malnutrition on the ^{14}C-Lysine Metabolism in Young Rats

In the usual laboratory animals the typical corollaries of chronic shortage of proteins, fats, and carbohydrates have been thoroughly studied. Very little is known, however, of the changes in the intermediary metabolism. Since we were interested from a pædiatric point of view in the problems of malnutrition, we have investigated weanling Wistar rats (bodyweight 35 ± 5 gm.). Five groups of ten animals each received for one week or more a synthetic diet (adapted from György) of the composition shown in Table 1.

Table 1

	Group I	Group II	Group III	Group IV	Group V
Carbohydrates	69		5	85·4	74·3
Proteins	20	50	68	2	21·4
Fats	6·7	per cent	22·7	8·3	(
Salts, vitamins and 'Nestargel *R*'	4·3	of Group I	4·3	4·3	4·3

On the seventh, eighth, and ninth days two animals of each group were placed in a metabolism cage. After adaptation to the new surroundings, each animal was injected intraperitoneally with 10μc_ε.^{14}C-lysine. Six hours later the animals were killed and the proteins of the different organs were isolated and their specific activity was determined in a methane flow counter as described in detail elsewhere[1].

A diminution of the calorie intake of 50 per cent did not influence the rate of incorporation of the labelled lysine into the proteins of any organ examined. This finding is in accord with the studies of Allison[2], and Cox *et al.*[3], which were based on results of experiments done with classical methods.

The results from our Groups III and V showed that there is no difference in the protein-sparing action of fat and carbohydrate, so far as it is possible to draw this conclusion from experiments with a single labelled amino-acid. But this finding agrees well with results obtained by the usual metabolic methods[4]. Of course only monosaccharides show a specific depression of the amino-acid-level in blood in experiments of short duration[5]. Fructose does not bring about higher retention of nitrogen than glucose[6] as has been claimed by others[7]. The specific activities of the organ proteins were in the same range as those of the group on a mixed diet (Group I). This is remarkable since the rats of Group III received a diet very rich in protein.

On the other hand, the animals on the diet almost free from protein, as is seen from Table 2, incorporated tagged lysine in several organs at a significantly higher rate than those of all the other groups. Since the carbon-14 dioxide production from lysine was only about 50 per cent of the other animals, one can postulate that the oxidative deamination of the amino-acid decreased in the protein-free animals in favour of protein synthesis.

Table 2. Specific Activity of the Proteins of Organs of Protein-starved Rats compared with Normally Fed Animals (taken as 100 per cent)

Organs	6th day	8th day	9th day
Liver	137	223	412
Kidney	131	184	279
Heart	128	186	300
Brain	107	245	726
Intestines	109	116	280
Muscle	65	85	73
Skin	90	85	83
Plasma proteins	221	212	251
Erythrocyte stroma	26	10	23
Hæmoglobin	81	8	22

Recently, Russian authors[8], in work on dogs, and also Garrow[9] and Waterlow[10], made similar observations; their experiments were carried out with ^{35}S-methionine.

Since we believe that protein synthesis is possible only when all necessary amino-acids are available simultaneously, one may postulate that, in protein starvation, the size of the pool of amino-acids is increased in those organs in which a higher rate of incorporation of ^{14}C-lysine is detectable. This can of course occur through a decreased breakdown, as we found to be the case in our animals. Lysine as such is not able itself to accelerate protein synthesis.

The radioactivity on the deproteinized blood plasma of the protein-starved rats was lowest in all the groups. In the liver, nevertheless, we had a relatively high count. Kreuger and Wiss have found with the microbiological amino-acid method a high content of free amino-acid in this organ in starved animals. Since the carcass proteins apparently do not partake in the increase in the rate of incorporation of lysine, it is evident that re-direction of the protein metabolism takes place in favour of vital enzymes and structures in the intestinal organs.

This interpretation is supported by the work of Solomon and Tarver[11] and of Waterlow[10], who have also found a shift in the rate of incorporation between the peripheral organs and the intestines. The changes in protein metabolism due to a protein shortage in the diet of longer duration proceed apparently in two phases: first, labile proteins which have a very short half-life are mobilized from the liver, etc.; later the 'less vital' structure proteins of the carcass are broken down and erythropoiesis is slowed down, whereas in the liver, kidney, intestines, and surprisingly in the brain too, neosynthesis is very active. The effect of protein starvation on protein synthesis is somewhat similar to that of glucocorticoids, which according to Hess and Shaffran increase the specific

activity of liver proteins and decrease the rate of incorporation into the connective tissue and muscles.

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PHYSIOLOGY

Dextran and Insulin in Rats

While testing the effects of insulin on the circulatory reaction of laboratory rats to dextran, we found that many animals died after combined doses of the two agents which were not lethal when administered separately. The validity of this observation was put to experimental test. Male Sprague-Dawley rats weighing at least 150 gm. and fasted 24 hr. were subcutaneously injected with zinc insulin ('Iletin') at two dose-levels, 7·5 or 10 u./kgm. body-weight. An hour later dextran was administered by vein in a total volume of 10 ml./kgm. 0·85 per cent sodium chloride containing either 60 or 600 mgm. dextran ('Expandex'). Control animals received saline without dextran. Fatalities due to these amounts of dextran have not occurred in our work. The results of eight experiments are summarized in Table 1, which shows the incidence of survival after 24 hr. Animals that died exhibited convulsions usually within 3 hr. of insulin administration. Few signs of the dextran reaction characteristic of this species were noticed.

Table 1. Effect of Intravenous Administration of Dextran on Survival of Fasted Rats after Insulin

Insulin	Dextran (mgm./kgm.)		
u./kgm.	0	60	600
7·5	16/20	5/20	13/20
10	13/26	4/26	20/26

No. survived/total number

The smaller dextran dose caused more stress than the larger at both insulin-levels. Comparison between the insulin doses (2 × 3 table) showed the results were not significantly different, so they were combined. The data were tested in 2 × 2 tables using χ-square with Yates's correction. Although not independent, these tests indicated that the decreased incidence of survival after 60 mgm./kgm. dextran was highly significant when compared with controls or with the number surviving after 600 mgm./kgm. The incidence of survival in the latter groups did not differ significantly from each other.

Aggravation of the dextran reaction in rats measured by œdema and blueing has been reported to follow insulin pretreatment[1,2]. We have found no previous mention, however, of the effect of dextran on this species' reaction to insulin, possibly because the observations were not continued long enough, or the insulin dose was too small. The occurrence of fatal convulsions after insulin doses which without dextran are subconvulsive may be due to indirect effects of dextran. One of these is severe and prolonged vasodepression[3], which would accentuate the already low glucose-level in the central nervous system. This situation could also prevail if vasoconstriction comparable to that seen in the mesoappendix and skin of the rat after intravenous administration of dextran[4] occurs likewise in the small vessels of the brain. Possible direct effects of dextran on resistance to insulin include changes in cellular permeability and blood sugar. Insulin in amounts too small to change the level of blood-sugar significantly has been reported to enhance œdema formation after subcutaneously administered dextran[5]. Our investigations of the manner in which dextran administered by vein affects insulin hypoglycæmia and the incidence of convulsions are continuing.

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Summative Action of Acetylcholine with Physiological Stimulus on the Generator Potential in the Lateral Eye of the Horseshoe Crab

The action of acetylcholine on the electrical activities of various receptors has been studied by many authors[1]. Most of the investigations of its action were carried out on the responses of receptors in terms of impulses they discharge. In this communication the effect of acetylcholine on the retinal slow potential, which is regarded as a generator potential[2], was studied by means of intracellular micro-electrodes. The electrical activities arising within single ommatidia of the excised lateral eye of the horseshoe crab (*Tachypleus tridentatus*), which was immersed in the physiological saline solution[3], were led to a cathode follower through a micro-electrode filled with 3 *M* potassium chloride.

Having obtained the responses by illumination of a given intensity, duration and interval as controls (*a* in Fig. 1), the solution made by dissolving acetylcholine chloride in physiological saline solution was added by a micropipette to the external solution of a known volume. Then the responses by the same stimuli were successively recorded. The concentration of acetylcholine was calculated afterwards.

As seen in Fig. 1*b*, a remarkable increase in the amplitude of both the initial maximal and the successive less but steady depolarization was induced by the addition of acetylcholine. Moreover, prolongation of the falling phases of the initial maximal depolarization and the phase of repolarization following cut-off of the stimulus also occurred.

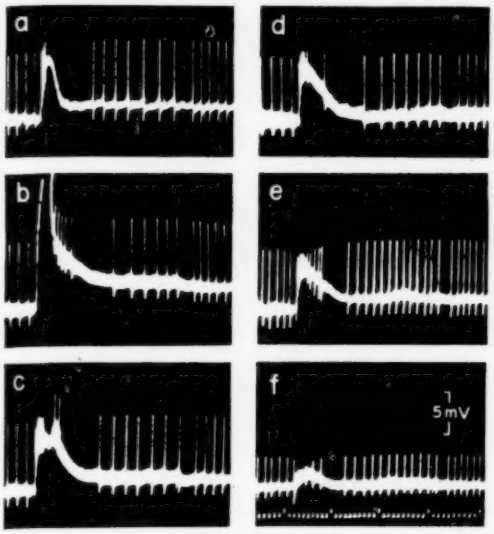

Fig. 1. Summative action of acetylcholine with illumination on the retinal slow potential. *a*, Control; *b–f*, records taken successively at every two minutes following addition of acetylcholine (5×10^{-4} mole). All records were obtained after 60 sec. in darkness. Pips indicate on- and off-signs. Time, 1 + 0·1 sec.

These effects could be obtained without any significant change in the resting potentials soon after the addition of acetylcholine. Sometimes two humps were formed as a result of the appearance of another hump at the falling phase of the initial maximal depolarization (Fig. 1*c*). This effect of acetylcholine on the generator potential of the eye of the horseshoe crab suggests that its summative action with natural stimuli reported in some other receptors may, at least, be partially due to its effect on their generator potentials.

The summative effect of acetylcholine was always followed by its depolarizing action (Fig. 1*d–f*), and the activity of the cell did not return to normal by application of normal saline solution.

Strychnine and 2,4-dinitrophenol elicited a reversible increase and a prolongation of the retinal slow potential of the horseshoe crab. But the effect of acetylcholine was more difficult to find, for an unknown reason, than that of the former two chemicals, though it was more remarkable at a lower concentration if it did appear. In most cases only the depolarizing action was exhibited following the addition of acetylcholine. The dosage differed from one preparation to another, as reported in other receptors[1], and the minimum effective concentration was 5×10^{-5} moles in our experiments.

In addition, the mode of action of acetylcholine is somewhat different from that of TEA. The latter compound belongs to the quaternary ammonium compounds as does acetylcholine, but it exhibited not only the summative action with natural stimulus but also induced spontaneous pulse-shaped prolonged potentials in the presence of sodium ions, as is reported in the giant axon of the squid[5].

Fuortes[4] suggests that the photoreceptor in the *Limulus* eye liberates a chemical product during illumination. But there remain difficulties in assuming that acetylcholine is the product in question according to our observations, since its summative action with natural stimulus could appear separately from its depolarizing action, and seemed not to be influenced by atropine or anticholinesterase in the experiments performed so far.

In any event, acetylcholine seems to have two actions on the sensory cells in ommatidia of the horseshoe crab; one is the summative action with physiological stimulus which may be explained as the sensitization of the chemical product or acceleration of its liberation during illumination, and the other is its depolarizing action on the cell membrane concerned.

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*p*H Changes during Muscle Twitch and Tetanus

DUBUISSON[1-3] has shown that *p*H variations during muscle activity can be recorded at the muscle surface with a glass electrode, using an electrometer and a sensitive galvanometer. Displaying the d.c. amplified electromotive force changes of the glass electrode, on the screen of a cathode-ray tube, reduces the recording delay to a few msec., and makes it possible[4] to estimate the time constant of the glass electrode (McInnes type), transmitting a *p*H step, to be about 30 msec.

The recordings during muscle activity are made with a small electrode (20 mm. long, diam. of flat sensitive membrane, 4 mm.). It is attached laterally to the hanging muscle, and a counter-weight arrangement makes it follow the muscle movements.

Fig. 1 shows the *p*H changes during single isometric twitches of a tortoise muscle at 22° C. The curves have been corrected[5] to take into account the diffusion time of carbon dioxide through the film of liquid and inert material (6μ) between the electrode and the muscle surface. The zero of the time-scale coincides with the beginning of the action potential, which is recorded in an attenuated form by the electrode. This introduces some uncertainty at the beginning of

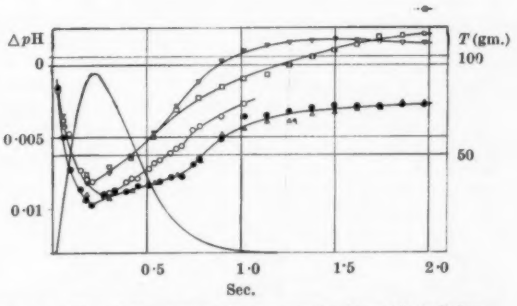

Fig. 1. *p*H variation during four successive isometric twitches (first twitch below, acidification downwards). Tortoise ileofibularis, *p*H 7·2, 22° C. Right ordinate: tension in gm.

the *p*H curves ; but careful examination of hundreds of records leads to the conclusion that the initial acidification (phase *b* of Dubuisson) does start during the action potential. The much slower alkaline shift (phase *c* of Dubuisson linked to phosphagen breakdown) is often absent during the first twitches sustained by a muscle after a long rest and builds up gradually to a maximum during following twitches. The fast acid phase is always present. Its Q_{10} is high, ~3·2 for tortoise muscle and lies between 3·2 and 3·8 for frog muscles.

If this initial change in *p*H is assumed to be due to the hydrolysis of ~P bonds, from adenosine triphosphate or any other carrier provided it liberates the same amount of H^+ at a given *p*H according to its electrotitration curve, one can calculate the amount of split ~P if one further knows the cellular carbon dioxide/bicarbonate ratio, the pK' of carbonic acid, and the retention factor which accounts for other buffer systems. Taking a minimum of 1·10 for this factor, values between 0·04 μmole/gm. and 0·1 μmole/gm. for tortoise muscles and 0·06 μmole/gm. and 0·18 μmole/gm. for frog muscles are found for the amount of ~P split per twitch. The best results correspond to 60–70 per cent of the minimum expected change (0·25 μmole/gm. for frog muscle) estimated from myothermic data[6]. The discrepancy, if not real, might be due to an under-estimation of the retention factor which is calculated from equilibrium measurements.

The *p*H variations observed during a single twitch are summed during tetanus, giving rise to *p*H curves similar to that described by Dubuisson. Assuming that a diphasic *p*H change is produced at each stimulus, in the range of frequency investigated, the experimental records can be reconstructed by simple algebraic summation, as shown in Figs. 2 and 3. It is seen that in these particular cases the absorption of H^+ overcompensates the H^+ liberation after a few stimuli, and that a linear steady state is established, which abruptly ends when stimulation stops. The final alkaline burst is in fact made visible by the cessation of H^+ production. The rate of H^+ liberation, corresponding to the accumulation of the fast acid changes described for single twitches, can be calculated from the *p*H recordings, and one obtains the curves shown in the upper sections of Figs. 2 and 3, giving the carbon dioxide production in μmole per c.c. of extracellular liquid.

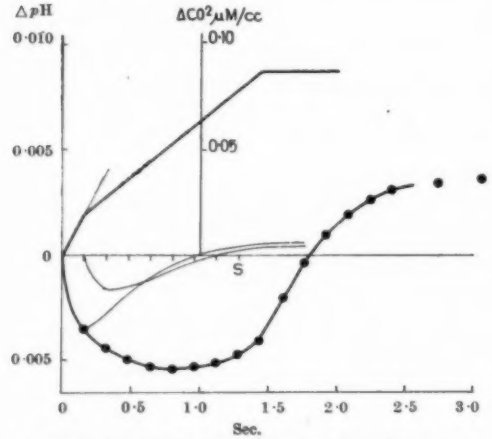

Fig. 2. *p*H change (full line downwards) during short tetanus. Tortoise iliofibularis, *p*H 7·0, 22° C. Stimulation ends at *S*. The circles are calculated by summing diphasic *p*H changes produced at each stimulus. Above: carbon dioxide production (μmole/c.c.) corresponding to the sum of the fast acid phases

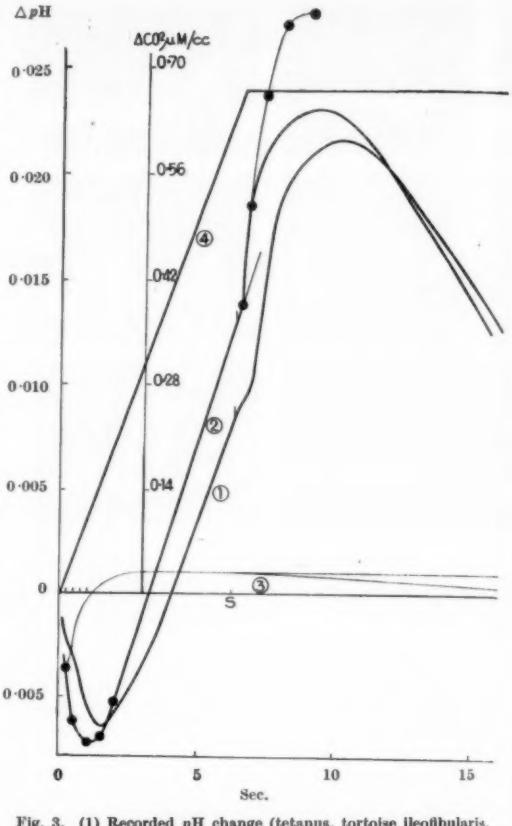

Fig. 3. (1) Recorded *p*H change (tetanus, tortoise iliofibularis, *p*H 6·8, 22° C.). (2) *p*H curve corrected for the lag due to diffusion. The circles result from the summation of 26 diphasic *p*H variations corresponding to a single twitch (curve (3)). Introducing a slow component in (3) leads to curve (2). Curve (4) represents the sum of successive fast acid phases, in μmole carbon dioxide/c.c.

If one admits that phase *b* of Dubuisson corresponds to an exothermic reaction (~P splitting) and phase *c* to an isothermic process (~P transfer), there is a good qualitative agreement between the H^+ production and the heat production during tetanus[7].

Quantitatively, the calculated rates of liberation of energy are, however, too small to account for the whole of the maintenance heat in the same proportion as observed for single twitches.

The intensity of phase *b* is linked to previous work done by the muscle and depends on the initial length. Qualitative indications exist such that the H^+ liberation during isotonic contractions depends on the amount of shortening.

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Metabolism of Oxygen-15

Oxygen-15 has been prepared by deuteron bombardment of nitrogen molecules in the Medical Research Council cyclotron at Hammersmith Hospital. Gases labelled with this isotope, which has a half-life of only 2 min., can be inhaled into the lungs and detected by external scintillation counters. The initial counting-rate in a given region of the lung is proportional to the regional ventilation[1], and the rate of removal from the region during breath-holding is a measure of the regional blood-flow[2].

During some of these experiments the radioactivity in the blood was measured at intervals after the breath was taken. Blood samples were taken from a forearm vein in four subjects between 15 sec. and 4 min. after the beginning of the breath of air, the oxygen of which was labelled with oxygen-15. The samples were heparinized and centrifuged for 2 min. to separate the cells from the plasma. The radioactivity of 2-ml. samples of red cells and plasma was measured in a sensitive 'well' type crystal scintillation counter. In a further study, 20 ml. fresh blood at 37° C. was labelled with oxygen-15 by bubbling a stream of the isotope in air through it. A sample was taken from the blood immediately after labelling and after 5-min. incubation at 37° C. and the radioactivity in both red cells and plasma was measured.

A typical example of the changes in the radioactivity in the plasma and red cells for 4 min. following the breath of oxygen-15 (corrected for radioactive decay to a common zero time) is shown in Table 1. The radioactivity in the plasma increased rapidly and the red cell activity fell during the 4 min. of observation. In consequence the proportion of the radioactivity in the plasma increased from 10·6 per cent after 30 sec. to 53 per cent after 240 sec. The results in all four normal subjects followed a similar pattern.

When blood was labelled *in vitro* only 1 per cent of the radioactivity appeared in the plasma, and this proportion did not alter significantly after 5 min. incubation. This is the proportion which would be expected from the known partition of molecular oxygen between red cells and plasma.

The rising plasma radioactivity found *in vivo* must represent the return to the plasma of oxygen-15 which has been metabolized in the body cells. The results show in a striking way how rapidly this takes place. An appreciable fraction of the inhaled molecules of oxygen-15 is transported by the blood to the tissues, diffuses into the tissue cells, is metabolized and then diffuses back into the blood within 30 sec. of the beginning of the breath.

An attempt was made to fractionate the radioactivity in the plasma into carbon dioxide and water by acidifying and shaking under vacuum, but none of the radioactivity could be removed. This is because oxygen-15, which is metabolized to carbon dioxide, becomes freely exchangeable with the oxygen in water when bicarbonate is formed in the blood, and therefore cannot be separated.

Table 1. Red Cell and Plasma Radioactivity corrected for Radioactive Decay to a Common Zero Time

Time after breath (sec.)	Red cell radioactivity (counts/min./ml.)	Plasma radioactivity (counts/min./ml.)	Ratio plasma/red cell activity (per cent)
30	102,000	10,800	10·6
60	104,000	12,500	12
120	78,000	21,600	28
240	55,000	29,000	53

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The Membrane Potential of the Anterior Byssus Retractor Muscle of *Mytilus edulis*

As yet no reports of intracellular recording from the anterior byssus retractor muscle appear to have been made. The membrane potential can be measured with coventional glass micro-pipettes filled with 2·5 *M* potassium chloride, but satisfactory recordings have only been obtained with electrodes possessing tips of about 0·5μ or less in external diameter. Very few such electrodes are free from large tip potentials; but some satisfactory recordings have been obtained from the muscle *in situ*, using selected electrodes.

The animal was opened and the muscles of one side cut through leaving the byssus attached to one anterior byssus retractor muscle in one half of the shell. The shell was mounted horizontally and filled with sea water, and tissue covering the anterior byssus retractor muscle was carefully cleaned away, leaving the muscle exposed. The recording electrode was connected direct to the grid of a cathode follower (6*BS*7 selected for low grid current) through a silver–silver chloride/sea water–agar bridge. The sea water in the shell was earthed via a similar bridge. Calibration voltages were applied across a 50-ohm resistor between earth and the shell. Signals from the muscle were taken through a d.c. amplifier and displayed on a pen-writing oscillograph. Membrane potentials recorded fell within the range 30–50 mV., but potentials from the same muscle were within a range of 7 mV. or less. The mean value was 39 $\pm$ 2 mV. (*S.E.* of 14 observations).

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Effect of Size of Pupil on Visual Acuity

Denton[1] has suggested that a possible function of the pupil light reflex might be to provide apertures optimum for visual acuity at different light intensities. At low levels of luminance visual acuity is probably limited by the rate at which light quanta activate the retinal receptors[2], and thus a large pupil admitting the maximum amount of light would appear to be advantageous. As the luminance is increased into the photopic range, loss of image contrast due to optical aberrations, diffraction, and stray light also tend to limit visual acuity, although the fineness of the retinal cone mosaic may ultimately become the limiting factor. The decrease in pupil size which normally accompanies increase of illumination should reduce to some extent the deleterious effects on visual acuity of the optical aberrations. However, it has never

been shown that the actual response of the pupil reflex to a given steady luminance does in fact result in an aperture giving maximum spatial resolution at this luminance. It was therefore decided to determine experimentally whether an optimum aperture existed at each luminance-level, by measuring the relations between pupil size, luminance, and visual acuity over a wide range.

In these experiments the pupil was dilated by instilling 2 per cent homatropine hydrobromide into the conjunctival sac. The instrument used to measure visual acuity at different luminances consisted of a tube 33 cm. long and 3 cm. in diameter. At one end of the tube was placed a disk, carrying apertures 1–8 mm. in diameter at 0·5 mm. intervals, which could be placed close to the eye so as to act as a variable entrance pupil. Close to this artificial pupil was placed an adjustable neutral wedge filter. At the other end of the tube was situated a circular ground-glass screen, subtending an angle of 5°, which was illuminated by an opal tungsten lamp of colour temperature 2,800° A. Luminances were measured with an *S.E.I.* photometer (Ilford) that was checked periodically against a calibrated standard lamp.

To measure visual acuity, a test pattern was placed in a holder in front of the ground-glass screen. The test pattern finally adopted contained a series of grating patterns with lines of different separation, each grating consisting of three opaque bars on a translucent background, the separation of the bars being equal to their width. All the different patterns are visible at the same time, avoiding the necessity of changing the pattern between each reading. The subject was instructed to look at a given pattern and then to increase the luminance by moving the wedge until the separate lines of pattern were just discriminated. Only vertical lines were used so as to eliminate the effects of uncorrected astigmatism. Lenses could be placed close to the eye to correct for refractive errors and also to allow for the proximity of the test pattern. The four subjects used were experienced at making visual observations of the type occurring in these experiments.

The results from a single typical run are shown in Fig. 1. Each curve represents the lowest luminance at which a given test pattern can be discriminated at various pupil sizes. For example, the largest test object used subtended an angle of 5·7 min., and it is clear that with increase of pupil diameter the test object is

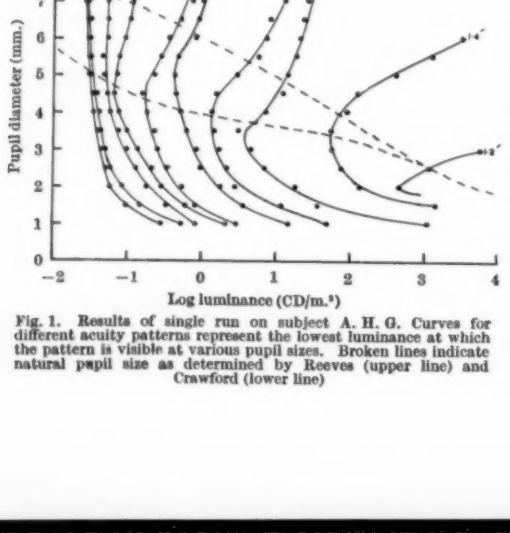

Fig. 1. Results of single run on subject A. H. G. Curves for different acuity patterns represent the lowest luminance at which the pattern is visible at various pupil sizes. Broken lines indicate natural pupil size as determined by Reeves (upper line) and Crawford (lower line)

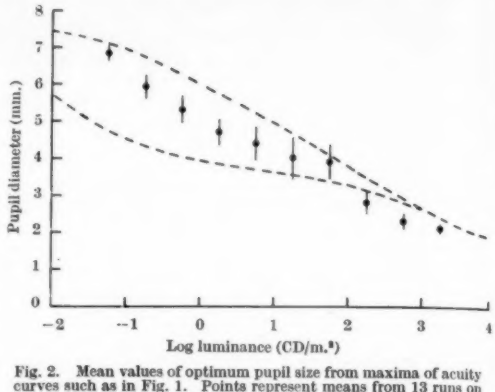

Fig. 2. Mean values of optimum pupil size from maxima of acuity curves such as in Fig. 1. Points represent means from 13 runs on 4 subjects, and extent of vertical lines indicates standard error of mean. Broken lines indicate natural pupil size as in Fig. 1

perceived at successively lower luminance-levels up to the maximum pupil size of 8 mm. However, for smaller test objects the minimum luminance occurs at pupil diameters less than 8 mm., and with reduction of test object size the optimum pupil diameter decreases progressively from 8 to 2 mm. All the curves show a rapid increase in threshold luminance as the pupil diameter is decreased below 2 mm., presumably due to the dominance of diffraction effects[3,4].

The smaller test patterns show a well-defined optimum pupil size, the threshold luminance increasing rapidly for pupil sizes on either side of this optimum value. For large test objects, the optimum pupil size is less well defined, and for even larger objects, involving parafoveal vision, the threshold will still be decreasing when the maximum available pupil diameter of 8 mm. is reached.

The results in Fig. 1 are from subject A. H. G. (age 23 years). Three other subjects, F. W. C., J. G. R., and R. R. (ages 35, 22, 26 years respectively) gave similar curves. To determine whether the type of test target influenced the results, F. W. C. performed two runs on each of three different targets (Landolt C, multi-bar grating, and three-bar grating). The optimum pupil size was found to be independent of the type of test target, but as the three-bar grating proved to be most convenient, this was used for the remaining subjects. Three runs were performed on A. H. G. and two each on J. G. R. and R. R. The mean optimum pupil sizes for these thirteen trials on four subjects are shown in Fig. 2, the means being taken over successive units of 0·5 log luminance. The vertical lines indicate the standard error of each mean.

Reeves[5] and Crawford[6] have published measurements giving the natural pupil size (with binocular viewing) at different luminance-levels, the subjects being fully adapted to each level. Their mean results, for seven and ten subjects respectively, are shown by the broken lines in both Figs. 1 and 2. The difference in their mean value is more marked at low luminance-levels, and may well be due to the dependence of maximum pupil size on age[7]. In Fig. 2 the mean optimum pupil sizes determined as above can be compared with the mean natural pupil sizes as measured by Reeves and Crawford. Although only a small number of subjects was used, the correspondence is good. We therefore conclude that the human pupil light reflex subserves the useful role of adjusting the aperture of the eye so as to optimize visual acuity over a wide range of luminance.

With the evidence at present available, it is difficult to decide whether the performance characteristics of the light reflex have been determined genetically by natural selection or by modification resulting from experience in each individual. Direct correlation between optimum pupil size and attained pupil size at different luminance-levels in a series of individuals might indicate the origin of the performance characteristics of the pupil.

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RADIOBIOLOGY

Labilization of Deoxyribonucleic Acid in Thymus Nucleoprotein after Whole-body Irradiation

The effect of total-body irradiation on the nucleoprotein in the sensitive organs can be demonstrated by a decrease of the viscosity[1]. Besides this, it has been shown that there is also a "labilisation of deoxyribonucleoprotein-moiety"[2] after a total-body irradiation and probably "the chromosome breaks may originate mainly in the junction of DNA particles with histone"[3]. To explain the effect of irradiation on nucleoproteins, it is probably necessary to study in more detail the binding between the deoxyribonucleic acid and the protein before and after irradiation.

The work of Kirby[4] provides a basis for such studies. According to this author, deoxyribonucleic acid can be extracted from tissues with 90 per cent phenol only in the presence of certain anions. These anions apparently break the bivalent metal linkages between the acid and protein. A small yield of deoxyribonucleic acid can be obtained with water; at increasing salt concentrations there is an increasing yield of deoxyribonucleic acid until all the acid becomes soluble. This phenomenon has been used in the present work as a measure of the firmness of binding the deoxyribonucleic acid to its protein.

Rats of an inbred strain of our own were irradiated with 200-kV. X-rays (10 m.amp., 210 r./min.). Desired tissues were taken immediately after decapitation, cooled on solid carbon dioxide, weighed, and homogenized with nine volumes of ice-cold water. To 2-ml. aliquots of the homogenate were added 2 ml. of trichloracetate of different concentrations (0–10 per cent). After 30 sec., 4 ml. of 90 per cent phenol were added and the mixture was shaken for 20 min. at room temperature, then centrifuged (15 min. at 0° C., at 15,000*g*). The clear supernatant was assayed for deoxyribonucleic acid by Dische's method[5]. A maximum yield of deoxyribonucleic acid was obtained with 2 per cent trichloracetic acid, which is noted as 'total deoxyribonucleic acid', as the extraction of the thymus with 5 per cent trichloracetic acid according to Schneider's method[6] gives no considerably higher acid values.

Table 1. Amount of Deoxyribonucleic Acid extractable from the Thymus of the Rat with Phenol-Trichloracetate (mgm. Acid per gm. Tissue)

Trichloracetic acid final concentration	Normal thymus	Thymus 6 hr. after 800 r.	Thymus 12 hr. after 800 r.
(per cent)			
0	0·87 ± 0·202	2·33 ± 0·23	3·54 ± 0·83
0·5	0·89 ± 0·118	7·28 ± 0·69	8·85 ± 1·10
1·0	2·38 ± 0·38	18·42 ± 2·13	18·5 ± 0·1
1·5	27·1 ± 2·32	34·5 ± 0·85	28·4 ± 1·6
2·0	27·76 ± 0·73	32·65 ± 2·26	37·1 ± 2·5
5·0	20·8 ± 2·58	31·75 ± 1·5	42·2 ± 0·2

Each value represents 12–21 animals with standard deviation.

Table 1 presents the yields of deoxyribonucleic acid from normal thymus. After a whole-body irradiation, considerably more acid can be extracted from the thymus, especially with the more dilute trichloracetic acid solutions.

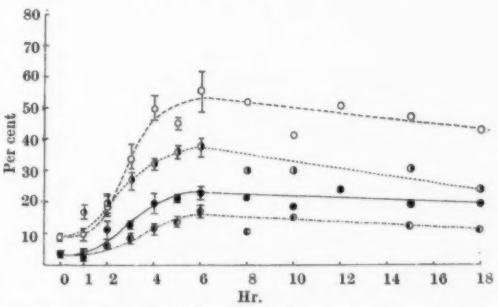

Fig. 1. Yield of deoxyribonucleic acid in extractions of thymus with phenol–trichloracetate after whole-body irradiation (yield in percentage of total acid). Time after irradiation. (Points with standard deviation represent 12–21 animals; single points represent three animals; trichloracetic acid final concentration in the supernatant). – – – ○ – – –, 1·0 per cent trichloracetic acid, 800 r.; – – – ◑ – – –, 1·0 per cent trichloracetic acid, 200 r.; ——●——, 0·5 per cent trichloracetic acid, 800 r.; –.–.–◐–.–.–, 0·5 per cent trichloracetic acid, 200 r.

The time relationships are more fully illustrated in Fig. 1. Since the total deoxyribonucleic acid per gm. of tissue changes after irradiation, the yield of deoxyribonucleic acid extracted with 0·5 and 1·0 per cent trichloracetic acid is calculated as percentage of the total deoxyribonucleic acid. After a lag period of about 1 hr., the yield increases for about 6 hr., after which it remains constant or decreases slightly.

The increase in yield of deoxyribonucleic acid extractable with dilute trichloracetic acid is dependent on the dose of irradiation. Table 2 demonstrates that the thymus of rats irradiated with as little as 50 r. differs significantly from that of controls.

The observed effect can be explained either by a break or weakening of some bivalent metal linkage

Table 2. Yield of Deoxyribonucleic Acid in Extractions of Thymus 6 hr. after Whole-body Irradiation with Phenol-trichloracetate

Dose	Trichloracetic acid 0·5 per cent	Trichloracetic acid 1·0 per cent
Control	3·2 ± 0·41	8·47 ± 1·32
50 r.	7·8 ± 1·57	22·6 ± 1·64
100 r.	9·8 ± 0·43	29·4 ± 2·2
200 r.	16·9 ± 1·93	37·55 ± 3·03
400 r.	21·9 ± 0·6	53·6 ± 1·5
800 r.	22·8 ± 1·77	55·3 ± 6·74

Each value represents 9–18 animals. Yield (per cent) of the total acid.

between deoxyribonucleic acid and protein, as suggested by Kirby[4], or by a higher concentration of deoxypolynucleotides in the thymus. As the increase of deoxypolynucleotides has been observed only for a short period after irradiation[3], whereas the increased yield of deoxyribonucleic acid remains constant for a longer period, the first assumption seems more likely. To obtain further evidence on this point, nucleohistone was extracted from the thymus with 1 *M* sodium chloride, precipitated by dilution to 0·14 *M* sodium chloride and used for further treatment with phenol–trichloracetic acid. As will be published later in detail, a similar irradiation effect can be observed as in the whole organ. From thymus-nucleohistone, prepared from animals 6 hr. after 800 r., 50 per cent of the deoxyribonucleic acid is extracted in 0·5 per cent trichloracetic acid, whereas from nucleohistone of normal animals, only 10 per cent deoxyribonucleic acid can be obtained in 0·5 per cent trichloracetic acid. This indicates a labilization of the deoxyribonucleic acid from the protein, probably due to a break in bivalent metal linkages.

This labilization occurs in an early post-irradiation period, that is, 1–6 hr. after irradiation. Histological observations demonstrate death of some cells at this time, although the weight of the organ and the deoxyribonucleic acid content per gm. of tissue begin to decrease later, namely, 6–10 hr. after irradiation. It seems probable that the labilization of deoxyribonucleic acid from protein occurs prior to histologically observable death of a cell. The distinct lag period of 1 hr. before labilization begins, however, suggests that some other processes in the nucleus are involved with it or responsible for it. In particular, the possibility must be investigated of a preliminary degradation of the deoxyribonucleic acid chain.

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Localization of a Halogenated Porphyrin in Mouse Tumours

Schwartz *et al.* observed that certain commercially obtainable hæmatoporphyrin preparations were contaminated by a porphyrin capable of becoming localized in experimental tumours[1,2], and that pure hæmatoporphyrin was unable to do so. These findings gave the impetus to the present work on halogenoporphyrins. The premise on the basis of which halogenoporphyrins were chosen was the assumption that the aforementioned impurity represents an intermediate formed in the course of the synthesis of hæmatoporphyrin from hæmin. One such intermediate could be *bis*-(2-bromo-ethyl)deuteroporphyrin. Since iodine-131 is a more convenient isotope for the purpose of labelling than isotopes of bromine, the iodine-131–labelled analogue was synthesized.

When given parenterally, *bis*(2-iodoethyl-^{131}I) deuteroporphyrin became localized selectively in transplanted adenocarcinomata of *Dba*1 mice and in spontaneous mammary adenocarcinomata of *C3H* mice. This conclusion is based on the following experimental findings. All tumours when examined 6 hr. after injection or later exhibited the red fluorescence characteristic of porphyrins; the fluorescence was non-uniformly distributed within these tumours. In contrast, none of the other tissues exhibited this phenomenon. Although extracts of organs from mice injected with *bis*(2-iodoethyl-^{131}I)deuteroporphyrin contained no porphyrins, radioactivity, probably due to products of porphyrin catabolism, was found to be present. When tumours or other tissues were extracted with a mixture of ethyl acetate/acetic acid (4 : 1, v/v), only the extracts of tumours contained detectable amounts of a single porphyrin. This porphyrin was identical with *bis*(2-iodoethyl-^{131}I)deuteroporphyrin with respect to its specific radioactivity. Furthermore, when the aforementioned tumour-extracts were chromatographed on paper strips and the developed chromatograms scanned for radioactivity, the radioactivity of the porphyrin-containing spot accounted for all the activity initially placed on the strip.

When sections prepared from a transplantable mammary carcinoma were examined after fixation in formaldehyde and after removal of paraffin with benzene, fluorescence typical of porphyrin was observed within the tumour cells. In the limited number of observations made, fluorescence was found to be present only in intact tumour cells.

The mechanism underlying the selective accumulation of *bis*(2-iodoethyl-^{131}I)deuteroporphyrin in the tumours studied remains to be established and is now being investigated.

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Synthesis of Diphosphopyridine Nucleotide in Irradiated Rats

When suspensions of nuclei from thymus or spleen are incubated *in vitro*, adenosine monophosphate in the nuclei is phosphorylated to the triphosphate[1]. This phosphorylation appears to be abolished following low doses of X- or γ-radiation, given either *in vitro* or *in vivo*[2]. However, the net synthesis of diphosphopyridine nucleotide *in vivo* following intraperitoneal injection of 0·5 gm. nicotinamide/kgm. (ref. 3) was not abolished when rats were exposed to X-radiation in doses up to 1,500 r. 3–60 min. before nicotinamide injection (Table 1); in these experiments, the pyridine nucleotide content of the tissue extracts was measured by the alcohol dehydrogenase method[4]. Since the synthesis of this nucleotide is restricted to the nucleus of the cell[5] and

Table 1. Increase in Concentration of Diphosphopyridine Nucleotide (DPN) in Rat Tissues 2 hr. after Injection of Nicotinamide

Tissue	Increase in concentration (μmol. DPN/100 gm. tissue)	
	Control	After exposure to 1,500 r.
Liver	135·0 ± 6·9	124·0 ± 12·5
Spleen	21·3 ± 1·4	20·1 ± 1·3
Thymus	8·4 ± 0·7	8·1 ± 1·5

requires adenosine triphosphate[6], the above result suggests that appreciable amounts of adenosine triphosphate are still available to the cell nuclei during the first two or three hours after irradiation.

The absence of phosphorylation *in vitro* following irradiation[2] might be due to diffusion of nucleotides and other water-soluble materials, for example, catalase[2], from the irradiated thymus and spleen nuclei into the suspending medium. An analogous loss of nucleotides and soluble enzymes does in fact occur during the isolation of nuclei from non-irradiated liver cells[7] and is probably responsible for the reported absence of nucleotide phosphorylation from suspensions of normal liver nuclei[3].

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HÆMATOLOGY

Isolation of Material with Proactivator Activity from Human Serum

In the scheme proposed by Astrup[1] to represent the stages in the activation of human plasminogen to plasmin by streptokinase, the substance designated 'proactivator' has hitherto been a hypothetical one, postulated to account for certain observations made by Astrup and his co-workers, but never isolated by them. American workers, notably Sherry *et al.*[2], have doubted the existence of proactivator, pointing out that all procedures available for the purification of human plasminogen result in parallel purification of the proactivator activity. Ablondi and Hagan[3] think that proactivator and plasminogen are probably identical.

By a process of acidification of serum to *p*H 3·3, followed by ether extraction after neutralization, we have obtained material ('A.E.S.') which has powerful proactivator activity but has no activator activity and contains no plasminogen.

We have found Astrup and Mullertz's[4] bovine fibrin plate method convenient for studying this material. Spotted on the fibrin plates by itself, it produces no lysis of the fibrin, that is, it does not activate the bovine plasminogen present in the fibrin, nor is it of itself proteolytic. On addition of streptokinase to the material, however, it causes marked lysis of bovine fibrin (Fig. 1). This activated material is not proteolytic for casein, showing that plasminogen is absent. Further proof that plasminogen is absent is given by the fact that addition of urokinase does not result in the appearance of proteolytic activity which would occur if plasminogen were present, as urokinase is a direct activator of plasminogen.

The bulk of the proactivator activity is precipitated by 40 per cent saturation with ammonium sulphate. The material obtained forms a very fine suspension on dialysis against distilled water, and does not go into solution on adjusting the salt concentration to 0·15 *M* sodium chloride. However, the greater part of the activity dissolves in borate (0·05 *M*) buffered saline at *p*H 7·4.

Following activation with streptokinase, the activator activity is also precipitated by 40 per cent saturation with ammonium sulphate, but the activator precipitate is highly soluble in borate (0·05 *M*) buffered saline *p*H 7·4.

Proactivator prepared in this way is an extremely stable substance, withstanding boiling at *p*H 1·5 for 30 min. without loss. Preliminary data suggest it is a cholesterol-containing protein. Activator is much less stable than proactivator, and is most stable in the *p*H range 6·0–9·0. 50 per cent of its activity is lost at *p*H 7·5 in 3 hr. at 37° C.

Tentatively, it is suggested that proactivator is activator bound to an inhibitor, the inhibitor being cholesterol or a lipoprotein containing cholesterol. This may provide support for the hypothesis that lipoproteins have an inhibitory effect on fibrinolysis[5] and an explanation of the observed inhibition of fibrinolysis by alimentary lipæmia[6].

Thanks are due to the director of the South African Institute for Medical Research (Dr. James Gear) and to the deputy director (Prof. J. F. Murray) for their encouragement and help in this work. Thanks are also due to Dr. A. Zoutendyk of the Serum Laboratories for abundant supplies of human serum, to Dr. J. Ploug (Leo Pharmaceuticals, Copenhagen, Denmark) for a generous gift of urokinase and to Mr. M. Ulrich for the photograph. This work was carried out with financial aid from the Council of Scientific and Industrial Research, Pretoria,

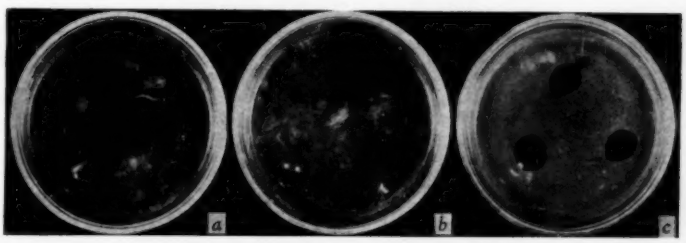

Fig. 1. (*a*) 30λ of a suspension of a 40 per cent saturated ammonium sulphate precipitate ('Fr. 40') of 'A.E.S.' spotted on an unheated fibrin plate (after Astrup and Mullertz). 18 hr. incubation at 22° C. No lysis. (*b*) 30λ of a 100 U./ml. solution of streptokinase ('Varidase', Lederle). 18 hr. at 22° C. Minimal superficial lysis only. (*c*) 30λ of an activated sample of 'Fr. 40'. 0·9 ml. 'Fr. 40' is incubated with 0·1 ml. streptokinase solution containing 100 U. for 10 min. at 37° C., then 'spotted' on the plate. 18 hr. at 22° C. Marked lysis: mean area 122 sq. mm.

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Serum Iron and Total Iron-binding Capacity in Certain Mammals

Data in the literature concerning transport of serum iron in animals are very sparse, especially those which may be directly comparable.

In previous work[1], we studied serum iron in six species of mammals and in hens.

It is well known how iron travels bound to a fraction of β-globulins (siderophilin or transferrin), and how its concentration in serum may be expressed as the maximum quantity capable of being bound (total iron-binding capacity). In man it amounts to about 340γ per cent[2] and in absolute values it represents 0·2–0·32 gm. per cent proteins[3]. Human serum normally shows its siderophilin saturated only to 30–40 per cent, while in pathological cases extreme values may occur. In certain conditions (pregnancy, ferropenia, etc.) the content of siderophilin is also clearly increased.

We have studied serum iron and the total iron-binding capacity in eight mammal species, human included, using Ramsay's techniques[4,5] and the results obtained are given in Table 1. The differences between average values have been submitted to a test of statistical significance (Student's *t*).

Thanks to statistical analysis it has been possible to show that serum iron does not show any intersexual or interspecific differences which are significant. But it must be pointed out that an intersexual difference in sheep is significant; however, we must disregard it for want of homogeneity in the ages of the males.

On the contrary, in the values regarding the total iron-binding capacity, there exist evident differences between species. The comparisons between sexes in each species have not proved statistically significant, and for this reason the values for males and females have been mixed up in order to carry out the interspecific comparison.

The values for total iron-binding capacity in the porcine species give an average of 476·8γ per cent, which proves statistically significant when compared with the other species.

We may also point out the low values obtained in donkeys, with an average of 263γ per cent which is also significant as regards the other species, except in mules. Goats have given, however, the lowest values (233γ per cent), but due to the lack of data about the males, goats have not been included in the comparison.

The differences between the average value of the total iron-binding capacity for cows and man, and for man and mule, are also significant.

A comparison between species of the corresponding saturation coefficient for serum iron proves significant only in the case of porcine species.

We therefore have a series of mammals, several of which show specific values of total iron-binding capacity, although their serum iron cannot be statistically differentiated. These differences in the total iron-binding capacity must be attributed either to quantitative variations of a definite siderophilin or to the existence of specific siderophilins, which would not constitute any exceptional fact if we

Table 1. Average Values for Serum Iron, Total Iron-Binding Capacity (TIBC) and SC* with Corresponding Extreme Values, Typical Deviations and Errors of the Average for the Species concerned, with Separation of Sexes, showing Number of Specimens in Each Group

	Males				Females			
Species	No.	Serum iron γ Fe (per cent)	TIBC γ Fe (per cent)	SC per cent	No.	Serum iron γ Fe (per cent)	TIBC γ Fe (per cent)	SC Per cent
Human	5	101·4 ± 11·4 (78–135) σ = 22·8	355·6 ± 12·5 (322–390) σ = 25·0	29·7 ± 3·4 (21·8–40·6) σ = 6·9	5	119·0 ± 13·0 (87–166) σ = 26·0	352·4 ± 14·2 (324–404) σ = 28·5	34·0 ± 3·7 (25·4–50·0) σ = 7·4
Porcine	6	104·0 ± 4·5 (85–102) σ = 11·0	496·5 ± 26·6 (375–562) σ = 58·7	21·4 ± 2·0 (15·1–29·8) σ = 4·4	5	113·0 ± 11·9 (75–152) σ = 23·9	453·2 ± 50·8 (303–600) σ = 101·6	24·9 ± 1·0 (21·1–27·7) σ = 2·1
Bovine	5	142·4 ± 22·1 (95–225) σ = 44·3	377·6 ± 34·1 (292–487) σ = 68·2	38·3 ± 3·9 (27·7–46·2) σ = 7·8	8	117·0 ± 4·7 (63–167) σ = 31·8	366·7 ± 34·0 (247–491) σ = 88·5	32·2 ± 4·2 (13·3–49·8) σ = 11·0
Sheep	6	114·5 ± 4·8 (100–135) σ = 10·7	283·5 ± 41·3 (187–442) σ = 91·0	44·4 ± 6·0 (24·4–61·4) σ = 13·3	5	136·4 ± 8·3 (117–157) σ = 16·7	291·8 ± 16·5 (243–336) σ = 33·1	47·7 ± 5·0 (34·5–59·6) σ = 10·1
Donkey	5	86·6 ± 4·5 (80–100) σ = 9·1	253·8 ± 3·8 (243–262) σ = 7·6	34·1 ± 1·8 (28·2–38·1) σ = 3·8	5	85·0 ± 14·5 (50–100) σ = 28·5	272·5 ± 19·8 (225–322) σ = 39·7	31·3 ± 3·3 (21·5–41·3) σ = 6·6
Equine	5	110·8 ± 11·0 (73–140) σ = 22·1	328·4 ± 20·6 (274–402) σ = 41·2	34·7 ± 4·5 (18·1–43·4) σ = 9·1	5	104·2 ± 11·1 (65–130) σ = 22·2	331·2 ± 20·1 (285–393) σ = 40·2	32·5 ± 4·8 (18·4–44·5) σ = 9·7
Mule	7	108·5 ± 9·7 (95–163) σ = 23·3	294·4 ± 18·6 (225–367) σ = 44·8	37·8 ± 4·5 (28·1–62·2) σ = 10·8	7	105·7 ± 6·9 (85–135) σ = 16·7	275·5 ± 20·0 (219–371) σ = 48·2	39·0 ± 3·1 (32·9–54·6) σ = 7·5
Goat					5	102·4 ± 8·5 (75–120) σ = 17·1	233·6 ± 24·4 (180–326) σ = 48·9	44·3 ± 4·3 (36·8–52·2) σ = 8·6

* SC = Serum iron × 100/total iron-binding capacity.

consider the existence of different genetic forms in man[6,7].

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Chromatography of Blood Thrombokinase on 'DEAE'-Cellulose

THROMBOKINASE, prepared from bovine plasma, has been obtained in a highly purified state by repeated electrophoretic fractionations[1]. However, a more efficient method was promised by anion-exchange chromatography, provided that the kinase could be separated from its accompanying impurities by stepwise elution in one day[2].

Fig. 1 illustrates an exploratory experiment in which purified kinase[3] from 21 litres of plasma was applied to a column of 2 gm. 'DEAE'-cellulose. Thrombokinase emerged in the last major band to be eluted by a series of potassium phosphate solutions. This opened up the possibility of recovering the kinase without appreciable dilution, if it were displaced by a strong eluant after protein impurities had first been removed by a weaker eluant. Such an experiment is presented in Fig. 2, where more than 90 per cent of the kinase in the original 19·2 ml. was recovered in the 20·5 ml. of the two best fractions. This was the product from 19·2 litres of plasma. Protein was estimated by the method of Lowry *et al.*[4]; and the total recovery was 91·3 per cent of the 44·4 mgm. put into the column.

The thrombokinase so obtained was diluted for some tests and dialysed for others, to avoid interference by phosphate. It could activate prothrombin in the presence of oxalate[5]; but it was much more

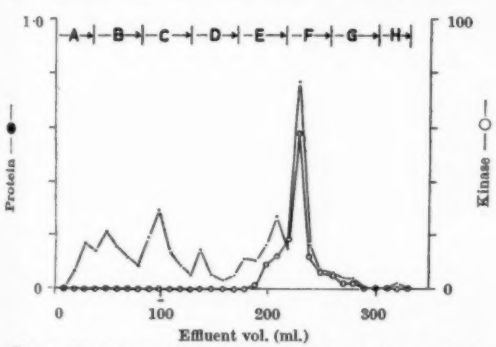

Fig. 1. Exploratory chromatography of thrombokinase. 4° C. Flow-rate 55 ml. per hr. *A*, thrombokinase in veronal, ionic strength 0·02, *p*H 8·6; *B*, 0·025 *M* phosphate, *p*H 7·84; *C*, 0·05 *M* phosphate, *p*H 7·88; *D*, 0·1 *M* phosphate, *p*H 7·88; *E*, 0·2 *M* phosphate, *p*H 7·90; *F*, 0·4 *M* phosphate, *p*H 7·95; *G*, 1·0 *M* phosphate, *p*H 8·20; *H*, 0·3 *M* phosphate, *p*H 4·40

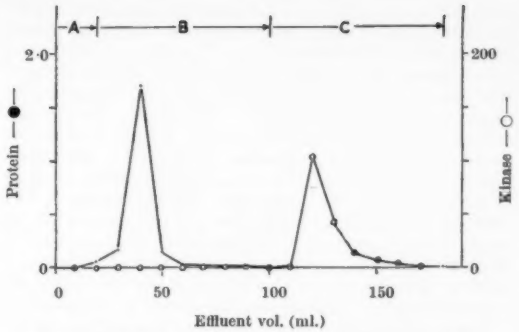

Fig. 2. Simplified chromatography of thrombokinase. 2 gm. 'DEAE'-cellulose. Column 1 cm. diam., 15 cm. high. 4° C. Flow-rate 27 ml. per hr. *A*, Thrombokinase in veronal, ionic strength 0·02, *p*H 8·6; *B*, 0·1 *M* phosphate, *p*H 7·88; *C*, 1·0 *M* phosphate, *p*H 8·20

effective when accompanied by calcium, cephalin and bovine barium carbonate-treated serum. In the latter system, the peak kinase fraction of Fig. 2 was assayed at a dilution of 1 to 1,200,000, corresponding to a protein concentration of 0·00088 μgm. per ml. The kinase activity of the fraction was 103 times that of the working standard. Because of the high dilution, and for other reasons[3], the assay cannot be considered precise. Nevertheless, the coincidence of protein and kinase data in the second band of Fig. 2 suggests an approach to homogeneity.

This suggestion is furthered by a comparison with the results of continuous-flow paper electrophoresis. In a third serial run by that method, almost all the protein appeared in a single peak[1]. There was a close correspondence of the data for protein and kinase, and also for tosyl-arginine methyl ester esterase, indicating that tosyl-arginine methyl ester is a substrate for thrombokinase. For the five chief fractions, the data for esterase units[6] per mgm. protein were 329, 359, 338, 333 and 325, with an average value of 337. Corresponding data for the two chief kinase fractions of the present Fig. 2 were 349 and 345. Although the agreement is good, further tests for homogeneity will be desirable, particularly since the present method was designed for preparative isolation rather than analysis. For the present, it may be noted that about the same amount of thrombokinase at this degree of purity was obtained in the experiment of Fig. 2 in one day as was previously obtained by electrophoresis, applied to the product from 738 litres of plasma over the course of several weeks.

Tosyl-arginine methyl ester esterase also occurred in the first band of Fig. 2; but this was associated with thrombin, which was found in the first band but not the second. Thus, the procedure separated thrombin from thrombokinase. In harmony with the findings of others[6], the tosyl-arginine methyl ester esterase associated with thrombin was not inhibited by crystallized soy bean trypsin inhibitor at a concentration of 1 mgm. per ml.

In parallel tests, the tosyl-arginine methyl ester esterase of the kinase band was mostly, but not quite entirely, inhibited. It has previously been shown that the trypsin inhibitor suppressed activation of prothrombin by blood thrombokinase in the presence of oxalate[7]. The general anti-thromboplastic effect of the inhibitor in the presence of calcium has long been known[8]; and recently it has been reported[9]

that thromboplastin-generating systems exhibited tosyl-arginine methyl ester esterase activity which was markedly inhibited by soy bean trypsin inhibitor.

It appears that thrombokinase, as described here, is an enzyme with some resemblances to trypsin. Its properties offer a unifying correlation for many diverse observations. The manner in which cephalin or platelet material augments the effect of thrombokinase is not completely understood. However, it is well to recall the suggestion of Macfarlane[8]: "It is possible in fact that cephalin, supposed by various workers to represent 'pure thromboplastin', is no more than a cofactor with calcium and a proteolytic enzyme (thrombokinase), potentiating the digestion of prothrombin and consequent release of thrombin".

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PATHOLOGY

Mast Cells and 5-Hydroxytryptamine in Precancerous Mouse Skin

A curious feature of carcinogenesis in the skin of the mouse is the intense mast-cell reaction which gradually develops in the dermis immediately under the painted hyperplastic epidermis. Cramer and Simpson[1] observed that some of these new mast cells exhibit a golden-brown fluorescence in ultra-violet light, providing that the frozen section has also been treated with formaldehyde.

Mast cells in the mouse (and rat) normally contain not only histamine[2] but also 5-hydroxytryptamine[3]. Riley[4] suggested that the golden-brown fluorescence exhibited by some mast cells, in formol-fixed sections, may indicate an abnormally high content of 5-hydroxytryptamine.

Attempts to localize the 5-hydroxytryptamine in pre-cancerous mouse skin by direct assay of tissue slices, though giving only a rough guide to the location of the amine (Cass and Riley, unpublished work), suggest that it occurs predominantly in the upper dermis. In the present work, histochemical methods applied to sections of precancerous mouse skin demonstrate with precision that the 5-hydroxytryptamine is concentrated in the granules of those mast cells which exhibit primary fluorescence in sections in fixed formol.

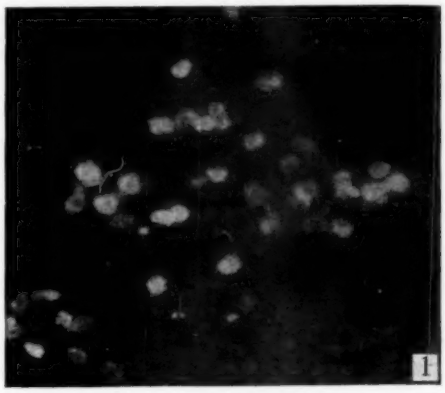

Fig. 1. Fluorescent mast cells at base of mouse skin papilloma. (× 400)

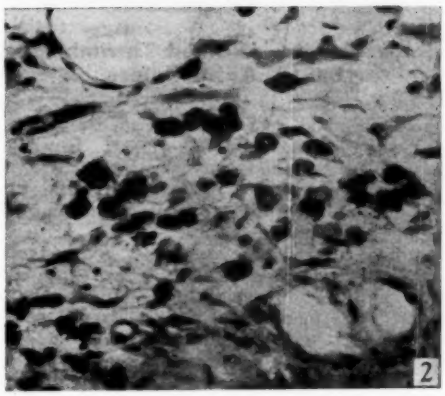

Fig. 2. Same field stained with toluidine blue. (× 400)

The dorsal skin of albino mice (Tucks) was painted on two occasions seven days apart with 0·5 per cent 9 : 10-dimethyl-1 : 2-benzanthracene dissolved in acetone. Animals which developed ulceration of the skin were discarded : the remainder recovered almost completely from an initial epilation and gradually developed papillomas or carcinomas over the next eight months. Animals were killed at varying intervals by cervical dislocation. The skin was fixed in formol–saline, formol–calcium or formol–dichromate buffered to *p*H 6. Frozen and paraffin sections were examined either in ultra-violet light (Leitz primary filter, 4 mm. *U.G.*1, secondary filter 2·5 mm. Euphos.) for fluorescence or in visible light after staining with

Table 1

	Chromaffin reaction	Toluidine blue	New methylene blue	Alkaline diazonium	Indophenol	Schmorl	Fluorescence
Precancerous mast cell granules	+ (faint)	+ + + metachromatic	+ + + metachromatic	+ +	+ +	+ +	+ + + golden yellow
Normal mast cell granules	−	+ + + metachromatic	+ + + metachromatic	−	−	−	−

+ + +, Strong reaction; −, no reaction.

one of the following methods: toluidine blue, New methylene blue, diazo-coupling with Garnet *GBC* salt or fast red *TR* at *p*H 9·2, treating with 2 : 6-dibromoquinonechloroimide (indophenol reaction[5]) or with Schmorl's ferri-ferricyanide mixture[6]. The most sensitive histochemical method, though not entirely specific for 5-hydroxytryptamine, was the Schmorl reaction applied to formol–calcium-fixed sections. However, it was often possible to apply more than one technique to the same section and so demonstrate convincingly that the specific staining reactions, described below, do occur in mast cells and not in other types of dermal cells with cytoplasmic granules. The results, which will be published in detail elsewhere, are summarized in Table 1. The methods referred to, except the chromaffin reaction, were all performed on formol–calcium fixed material.

The above findings, together with the results of direct assay (Cass and Riley, unpublished work), indicate that 5-hydroxytryptamine is concentrated in the mast cell granules. The number of positive cells increases during the induction period. A strongly positive reaction is most commonly seen in mast cells at the base of papillomas (Figs. 1 and 2), though a positive mast cell is occasionally seen elsewhere in the treated dermis. It is thus clear that the high level of 5-hydroxytryptamine in precancerous mouse skin is due not only to an increase in the number of mast cells in the area but also to a progressive increase in content of 5-hydroxytryptamine in certain of these cells.

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A Transplantable Spontaneous Osteogenic Sarcoma observed in the Muscle Tissue of an Albino Mouse

Osteogenic sarcomas attached to bone tissue have been reported in animals of different species. In 1936, Brues[1] described a case of spontaneous osteogenic sarcoma in the jaw of a three-year-old grey rabbit. Barrett *et al.* reported an osteogenic sarcoma attached to the left femur of a *C3H* female mouse[2]. Osteogenic sarcomas have also been induced by radioisotopes such as radium-226, strontium-90, calcium-45 (ref. 3) and strontium-89 (ref. 4). One case of osteogenic neoplasm arising from muscle tissue has been reported in man[5]. This tumour found in the thigh muscle had developed over a period of ten years and was believed to have followed an abscess in the muscle.

The tumour to be described was found an the soft tissue of the lateral neck region of a full-grown female mouse from our breeding colony. This colony was derived from *CF*1 mice of Carworth Farms. The host was a multiparous mother approximately six months of age. The neoplasm was situated between the muscle layers of the right sternohyoides and sterno-cephalicus muscles and the skin. It was approximately 1 c.c. in volume. This tumour has been designated *H*-7. An attempt was made to transplant it into the same strain of mouse as the host. The neoplasm was excised and macerated in a sterile mortar, adding an equal amount of normal sterile physiological saline. An injection of 0·1 ml. of the suspension was made into the subcutaneous tissues of the right hind leg of 5 male and 5 female mice. A satisfactory growth was obtained in 6 of the 10 mice of the first generation. At eight weeks tumour tissue was removed from these mice for a second transplantation using aseptic technique. Suspensions of the first-generation tumour found to be microbiologically sterile were injected into 16 male and female mice of the same strain. The growth-rate of the second generation tumour was increased and the tumour-take was 100 per cent. The tumour was removed at six weeks for resuspension and injection into the third generation.

Histologically the tumour presented the classical picture of osteogenic sarcoma with abundant bone formation. It is apparently as difficult to determine the exact site of origin of osteogenic sarcomas in animals as in man. The primary tumour in this case did not seem to have grossly an intimate fusion with bone. For this reason, the actual site of origin of the tumour is uncertain. Studies are at present being made of the cytology, histology and enzymatic characteristics of *H*-7 as well as its transplantability in homogeneous and heterogeneous host animals, detailed results of which will be published later.

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Treatment of *Leishmania donovani* Infections with Surface-active Agents

'Triton *W.R.* 1339', an arylalkyl polyoxyethylene ether of phenol, prepared by Rohm and Haas Co., Philadelphia, is a non-toxic surface-active agent, and was shown to exert a suppressive effect in experimental tuberculosis of mice[1]. 'Macrocyclon' is the polyoxyethylene ether containing on average 12·5 ethylene oxide units per chain, formed by reaction of ethylene oxide with a macrocyclic phenol and possesses similar antituberculous activity[2].

In view of these favourable results obtained, it appeared that the same drugs might be of value in treating other infections, such as kala-azar, in which development of the infecting agent also occurs in the white cells of the host.

Twenty golden hamsters were infected intraperitoneally with a strain of *Leishmania donovani* isolated from an Indian seaman and afterwards maintained by passage in these animals in which the

infection is invariably fatal[1]. Six weeks later, biopsies were made and the number of parasites per oil immersion field determined in smears of spleen. Intraperitoneal treatment with the two drugs named above in dosage of 125 mgm. was given on days 2, 5, 9 and 15 after biopsy to groups of six animals and a similar number of untreated animals were used as controls. They were killed three weeks later and counts were again made of the number of parasites in spleen smears. Although no cures had been effected the results indicated that the drugs had controlled the infection.

A second experiment was carried out in which thirty hamsters were infected as before. Treatment with 125 mgm. drug per animal was started on the day of infection and repeated 2, 6 and 9 days later. Five animals received similar treatment with each drug in absence of infection and survived. The infected animals were killed 8 weeks later and parasite-counts were made in smears of spleen. The results obtained are shown in Table 1.

Table 1. *Leishmania donovani* Bodies per Oil Immersion Field

Controls	'Macrocyclon' 4 × 125 mgm.	'*W.R.* 1339' 4 × 125 mgm.
120	15	26
100	6	8
100	5	1
50	3	<1
30	2	<1
20	1	<1
10	1	—
—	<1	—
—	<1	—
—	<1	—

In a further experiment thirty hamsters were infected and intraperitoneal treatment with 125 mgm. of each drug was given 4, 7, 11, 14, 18 and 20 days later. The animals were killed 7 weeks after infection. Five uninfected animals received similar treatment with each drug and survived. The results obtained are shown in Table 2.

Table 2. *Leishmania donovani* Bodies per Oil Immersion Field

Controls	'Macrocyclon' 6 × 125 mgm.	'Triton *W.R.* 1339' 6 × 125 mgm.
200	<1	<1
200	<1	<1
150	<1	0
100	<1	0
100	<1	0
50	<1	0
30	0	0
20	0	0
—	0	—

Cultures were made from spleen on Locke-serum-agar medium and all were positive, showing that infection had been controlled but not eradicated as the result of drug treatment.

Similar results have been obtained by Dr. F. C. Goble, Ciba Pharmaceuticals, Ltd., Summit, New Jersey, with 'Triton-*W.R.* 1339', and will be reported elsewhere.

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BIOLOGY

Delayed-type Hypersensitivity in Premature Neonatal Humans

It has been shown[1] that guinea pig embryos could be induced to develop the delayed-type of hypersensitivity[1]. The possibility that the premature new-born human could be similarly sensitized was therefore investigated. Successful sensitization of new-born humans to poison ivy has been reported[2].

Ten premature infants (average birth-weight 1,255 gm.) and five neonatal infants of normal weight were sensitized percutaneously during the first week of life with 0·02–0·04 ml. of a 10 per cent solution of 2,4-dinitrofluorobenzene in acetone. As controls, five infants between the ages of 2 and 12 months were similarly sensitized. 2–4 weeks later patch-testing was carried out with 0·01 molar 2,4-dinitrofluorobenzene in corn oil–acetone. The patches were removed at 48 hr., at which time the reactions were read.

Table 1. Contact Sensitivity to 2,4-Dinitrofluorobenzene in Human Infants

Group	Contact reactions 2 weeks*	3–4 weeks*
Infant (2–12 months)	5/5	Not done
Full-term neonatal	1/4	2/5
Premature neonatal	2/10	3†/10

* Time after sensitization.
† Birth-weights were 1,390, 1,080 and 1,650 gm. The first two of these infants received two sensitizing doses nine days apart.

As can be seen in Table 1, this sensitization procedure induced contact skin reactivity in all five of the older infants, two of five normal neonatal infants and three of ten premature new-born infants. The positive reactions of the neonatal infants appeared similar to those elicited in the older infants, but were usually less intense. There was no detectable relationship between the weight of the premature neonatal infant and its capacity to be sensitized. This is strikingly illustrated by one of the smallest infants in the experiment, who weighed 1,080 gm. at birth (indicating a gestation period of approximately 30 weeks) and yet showed a contact reaction at age three weeks. Moreover, the neonatal infants of normal weight did not appear to become sensitized any more readily than did the premature new-born infants.

Punch biopsy of a representative contact reaction at 48 hr. was performed in a premature infant. Histological examination of serial sections revealed an accumulation of lymphocytes and histiocytes in the dermis with invasion of the epidermis and resultant

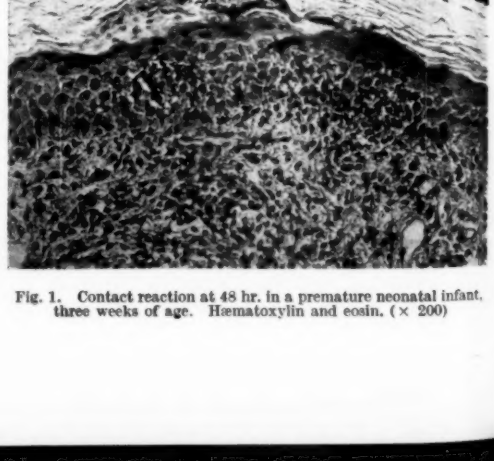

Fig. 1. Contact reaction at 48 hr. in a premature neonatal infant, three weeks of age. Hæmatoxylin and eosin. (× 200)

loss of the basement membrane (see Fig. 1). Microvesicles, spongiosis and an increase in mitosis were seen in the epidermis. The histology is consistent with that seen in contact dermatitis in the adult[3]. Patch testing 2–6 weeks after birth of unsensitized neonatals (six premature and six full-term) gave negative results. Punch biopsy with histological examination of a patch test area at 48 hr. in an unsensitized premature neonatal, aged three weeks, also failed to show an inflammatory reaction.

Our findings show the following striking similarities to previous work on antibody formation in new-born infants[4]: (*a*) delayed-type hypersensitivity and antibody formation can both be induced in premature infants during the first month of life; (*b*) new-born infants are inconsistent in their capacity to develop these two types of immune response; (*c*) premature infants become sensitized and form antibodies as efficiently as normal new-born infants.

This work suggests that the older human fœtus might be capable of an immune response if an appropriate antigenic stimulation could be administered *in utero*. The possibility is not excluded, however, that separation from the placenta is an essential step in the maturation of the immune mechanism.

We thank Dr. Philip Prose, of the Department of Pathology, for his assistance in the processing and interpretation of the skin biopsies.

This work was aided by grants from the Association for the Aid of Crippled Children, the National Institutes of Health (*E* 1821 (*C*-2)) and the Commission on Immunization of the Armed Forces Epidemiological Board.

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The Polychæte Family Longosomidae in New Zealand

In 1944 Hartman[1] described a new polychæte species *Longosoma catalinensis* from off Long Point, Catalina Island, southern California, founding a new family, the Longosomidae, to contain it. The original description was based on a single specimen, but afterwards in 1957 she reported 34 specimens from three stations off southern California in depths of 7–45 fathoms. According to Hartman[2] the species may have its affinities with the Paraonidae; but the possession of long, paired, grooved palpi, resembling those of spioniform annelids, allies it to the disomid and magelonid families.

The genus and family have not been recorded to date from other than the original locality, hence it was of great interest to obtain specimens of a polychæte, which at first were thought to be specifically identical with *L. catalinensis*, from such a distant locality as Hawke's Bay, New Zealand. The New Zealand specimens, numbering 27, were obtained in August 1956 from twelve stations, in depths of 8–64 fathoms, by Dr. D. Hurley of the New Zealand Oceanographic Institute, and I am indebted to him for the opportunity to report on this interesting discovery. On a recent visit to California, the New Zealand specimens were compared with the type of *L. catalinensis* and Dr. Hartman agrees that the differences justify the founding for them of a new species of the genus *Longosoma*. As in *L. catalensis* they have the body divided into an anterior region of nine short setigerous segments and an abdomen with greatly prolonged cylindrical segments, the abdominal parapodia consisting of ridges with double rows of simple setæ. The New Zealand species differs in its larger size, the largest posteriorly incomplete specimen of *L. catalinensis* with four abdominal segments measuring 25 mm., whereas a comparable specimen of the former measures 55 mm. They are also much more robust, with the thorax measuring up to 3 mm. across, and with the thoracic setæ heavier and more numerous. The proportionate length of the abdominal segments also differ, but the greatest difference is to be seen in the arrangement of the abdominal parapodia. In *L. catalinensis* the abdominal parapodia are low ridges encircling two-thirds to three-quarters of the body and leaving the ventrum plain, while in the New Zealand species the ridges are much more prominent and completely encircle the body. A full description of the species will be published separately.

It is of interest to note that Hartman records her specimens from similar depths in very fine sand and silt and in temperatures of about 14·9° C. The bottom sediments from the stations where the New Zealand specimens were obtained are recorded as ranging from fine grey sands to fine sandy muds with bottom temperatures in the region of 13·0–13·3° C. According to Hartman, *L. catalinensis* is associated with other polychætes, a maldanid, *Axiothella rubrocincta* (Johnson) and a nephthyid *Nephthys ferrunginea* Hartman, and a cumacean, probably *Diastylopsis tenuis* Zimmer. Some thirty-six species of polychætes have been recorded from Hawke's Bay in association with *Longosoma*, among the dominant being a nephthyid, *Aglaophamus verrilli* (McIntosh), and two species of maldanids of the genus *Asychis*. Other dominants include the cumaceans *Diastylopsis elongata* Calman and *D. crassior* Calman (belonging to the same genus as the cumacean associated with *L. catalinsis*), the holothurian *Cucumaria oconoides* (Dendy), ophiuroids of the genus *Amphiura* and the bivalves *Dosinia lambata* (Gould) and *Maorimacta ordinaria* (Smith).

The present recorded distribution of the family Longosomidae, southern California and northern New Zealand, represents a very disjunct distribution. In both localities the representatives of the family are not uncommon, and it is therefore surprising that it has not been recorded elsewhere. Additional distributions will, however, probably be recorded when similar shallow bottom areas of the Pacific basin are studied in detail, as has been done for the areas off southern California and Hawke's Bay, New Zealand. It is of interest that similar techniques were used in processing the bottom samples from the two regions. A similar disjunct distribution is recorded for the species of the echiuroid genus *Urechis*, which has been recorded from southern California, southern Chile, New Zealand, and Japan[3].

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Mouth and Blastopore

By the Haeckelian view of early development, gastrulation by invagination reflects the evolutionary history of primitive Metazoa. It is a corollary of this theory that gastrulation by ingression is a derived form of emboly. Nevertheless ingression, the method of endoderm formation among the lower cnidarians, is probably the more primitive mode of gastrulation, as observed by Metschnikoff[1,2], Hyman[3,4] and others. The diploblastic level of organization probably arose in early Metazoa by a process resembling ingression, or some other type of delamination, giving rise to solid planula-like forms. It is therefore probable that invagination is merely a developmental expedient, which has arisen secondarily and independently in the more advanced Cnidaria and other metazoan groups.

The blastopore results from invagination, narrowing as gastrulation progresses. In keeping with Haeckel's interpretation, it is generally thought to represent the primitive mouth. It may nevertheless be merely a product of the mechanics of development, without especial phylogenetic significance. The Cnidaria in which gastrulation occurs by ingression, while possessing a mouth and cœlenteron, have no blastopore or archenteron during development. It appears from the embryology of these cœlenterates that mouth and blastopore were independently acquired in early Metazoa. Furthermore, a mouth may have formed before the origination of embolic gastrulation and a blastopore. Following the evolution of embolic gastrulation, the blastopore preceded the mouth in embryonic development, for it relates to the fundamental process of germ-layer formation. Similarly, it appears that enteron and archenteron were independently evolved. Terms such as protostoma, Protostomia and archenteron are therefore strictly inapt.

The mouth in some non-cœlomate animals and Protostomia does not coincide with the blastopore or its point of closure. Also, in many higher cœlenterates, non-cœlomate groups and Protostomia the blastopore does not persist as a mouth, but closes before the mouth forms. This possibly signifies the evolutionary independence of the two structures.

It is generally agreed that the embryonic axis corresponds with the polar axis of ancient Metazoa, the animal pole representing the primitive perceptive and dominant region, directed forward in locomotion. Biologists who support the ingression theory, but identify the blastopore with the primitive mouth, believe that the mouth arose at the more inert end in a solid, diploblastic ancestral metazoan. This entails the puzzling conception of a structure for the selection and ingestion of food separated from the dominant, sensitive region of the body. It seems more probable that the mouth originally occupied an antero-ventral position.

In cœlenterates the mouth typically forms at the posterior end of the swimming larva, in the blastoporal region when gastrulation is by emboly, and does not change position during development. This may be a special feature correlated with the sessile habit of the polyp.

Typically, in cases of gastrulation by invagination, the gastrula presents two centres of high metabolic activity of different kinds: the animal pole, corresponding with the controlling and perceptive region of original Metazoa and larval forms; and the blastopore, a zone of rapid cell division, and a focus of developmental activity and organization. Among the Protostomia, the mouth arises in the blastoporal field, later coming to occupy an antero-ventral position. The mouth thus develops in a region of high formative activity, and may form from the blastopore, a ready-made aperture. This may be merely a developmental convenience. (By a similar short cut in development, in some Protostomia and Deuterostomia a persistent blastopore forms the anal opening.) In the embryonic development of many annelids, the blastopore elongates and constricts into two. One of the apertures so formed, the mouth, separates to its definitive ventral anterior position. The second aperture, remaining at the vegetal pole, soon closes. The anus later arises at this point. The division of the blastopore has been interpreted as separation of the mouth from a transitory anal pore. It more probably represents dissociation of the mouth from the blastopore.

Among the Deuterostomia, the mouth typically originates at an antero-ventral point. This is believed to indicate that the mouth has evolved anew and assumed the function of the primitive mouth, homologous with the blastopore. It is more probable that the mouth in the Deuterostomia occupies the original position, and the blastopore at no time functioned as mouth.

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Softening Chitin for Histology

The chitinous integument of many invertebrates consists not of chitin alone but also incorporates much structural protein. In the more highly sclerotinized arthropod shells, indeed, this may far exceed the true chitin. The methods frequently used for softening 'chitin' for histological purposes make use of this fact, and none of them actually alters the chitin itself, acting instead on the protein moiety of the integument. 'Diaphanol', for example, the most widely used agent for softening 'chitin', acts by breaking benzene rings in the aromatic amino-acid residues of the proteins[1]. Inevitably such an action is accompanied by extensive damage to the tissues of the specimen, for not only is the protein of the skeleton digested but also the proteins of the tissues which we wish to examine. The use of diaphanol, or of other agents which digest the protein moiety of the chitinous integument, is therefore incompatible with precise histological or cytological investigation. If the integument consists mainly of structural protein, then we have no way out of the dilemma except to dissect the tissues free from all traces of the offending shell. If, however, as in the less-sclerotinized shells, it consists chiefly of true chitin, then it is possible to attack the chitin enzymically, leaving the tissues untouched.

Possibly the best source of a suitable chitinase is the unripe puff-ball, *Lycoperdon* spp. Tracey[1] advocates this source of the enzyme for biochemical analysis. He suggests that the puff-balls should be torn up and pressed to yield a juice which, when buffered at *p*H 5 with acetate buffer, will readily digest chitin. This juice may be stored for a year or more in a refrigerator under toluene. I have used

this extract for softening chitin for histological purposes, but it contains also a number of other enzymes which damage the tissues that are under examination. Moreover, puff-balls are not readily obtainable. The common mushroom of commerce also contains large amounts of chitinase, and may be obtained at any time of year. The extraction outlined below may be applied to either mushrooms or to puff-balls, and yields a liquid which will keep for a year or more in the refrigerator and is relatively free from other enzymes that might detract from its histological usefulness.

100 gm. mushrooms are roughly torn up and steeped overnight in 100 ml. 35 per cent w/v sodium chloride solution. The chitinase is soluble in this saline, while most of the other enzymes are salted out and are present in the residue which is centrifuged off. This stock solution may be kept in the refrigerator without the addition of any preservative, as the salt concentration is above the limit for bacterial or fungal growth. For use it is diluted to an appropriate salt concentration either with acetate buffer at *p*H 5 or more simply with distilled water, relying on the atmospheric carbon dioxide to produce approximately the correct *p*H. For marine organisms a dilution of 1 : 10 seems appropriate, giving a solution nearly isotonic with sea water. The fixed specimens are washed well with running tap-water overnight to remove the last traces of the fixative, which might inactivate the enzyme. They are then incubated with the diluted enzyme preparation for 12–24 hr. at 37°. A little toluene may be added to prevent bacterial action, particularly if the chitin is thick and it is desired to continue incubation for a longer period. After incubation the specimens may be prepared for sectioning in the usual way. This technique has proved successful with the copepod *Calanus*, the prawn *Palaemon* and the insect *Locusta*. It is useless with heavily sclerotinized integuments, which have a high protein content and low chitin content.

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An Improved Feed for Experimental Fish[1]

It is well known that minced liver is an excellent food for brown trout (*S. trutta*) kept under hatchery conditions or under experimental conditions in aquaria[1]. In aquaria with a low water-flow the minced liver very quickly fouls the water. It has been found that if the liver is mixed with gelatine this difficulty can be avoided. As many workers now use these fish as experimental animals, it is felt that it would be useful to publish this fact.

The minced liver, previously salted with 5 gm. of salt per pound of liver, is mixed with 120 c.c. of a 33 per cent solution of gelatine. The whole is allowed to set and then reminced before feeding.

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Survival of Woody Plants at Extremely Low Temperatures

There are a number of things that should be pointed out in connexion with the communication by A. Sakai[1]. Various kinds of plant material have been cooled to these temperatures and even lower, yet they have survived[2–4]. My own work[5] revealed that leaves of *Pinus strobus* could be cooled to −90° C. in winter without apparent damage, and it was later shown that leaves of this same species could be cooled to −189° C. without damage as indicated by the tetrazolium test made several days after treatment[6,7]. Recently I have cooled buds of various deciduous trees to −80° C. at the rate of cooling and warming indicated in Table 1, and although some survived, others did not.

Table 1. Cold Resistance* of Tree Foliage in Deg. C. at New Haven, Connecticut, in January

Rate of cooling about 4° C. change per hr.; rate of warming about 8° C. change per hr. Most plants became still hardier in February

Plant	Origin	Resistance* ° C.
Abies guatemalensis†	Costa Rica	−6
Cupressus lusitanica†	Costa Rica	−10
Cryptomeria japonica	Japan	−20
Pinus palustris†	Northern Florida	−25
Ilex opaca	unknown	−35
Chamaecyparis pycifera	Japan	−42
Taxus baccata	unknown	−42
Tsuga canadensis	New Haven, Conn.	−45
Juniperus virginiana	Branford, Conn.	−52
Picea excelsa	Germany	−58
Tsuga canadensis	Branford, Conn.	−58
Pinus sylvestris†	Germany (?)	−62
Pinus strobus	New Haven, Conn.	> −189

* The lowest temperature which the leaves could withstand without being killed.
† Seedlings 1 to 6 years old.

I thus feel that Sakai's findings are generally in accord with my own and those of others. On the other hand, one gains the impression from Sakai's communication that if a plant can be cooled to −30° C. without damage it can be cooled on down far below this without any damage. Yet the winter resistance of several conifers can range all the way from a few degrees below freezing to below −189° C. (Table 1). But the rates of cooling and warming are most important in such work and should not be changed.

Finally, it should be understood that nearly any criterion of life or death can be at fault if not used in the correct way. Several days after the treatment is made, the tissue may die while controls survive. This error is particularly involved in plasmolysis tests which indicate the intactness of the outer vacuolar membranes but do not prove that the cytoplasm itself has not been injured. Judging by the tetrazolium test, enzymes may become less active over a period of time and finally show no activity, while untreated cells continue to reduce tetrazolium salts. The more severe the injury the more rapidly this change comes about after warming. In our experiments the time-lag effect in dying is a serious source of error in cold-treated leaves. Some leaves which survived in a moist chamber at 22° C. for two weeks died in the third week, while controls survived for at least three months.

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Jensen[1] has also claimed that the ability to plasmolyse in onion cells is not a reliable index to their viability, because he observed some abnormal cells in which vacuoles were normally stained by neutral red solution and tonoplasts still retained their permeability, having the cytoplasmic layers torn outside the tonoplasts. In a previous report[2] I stated that such abnormal cells have not yet been observed during several years study in the parenchyma cells of the cortex in woody plants, but some parenchyma cells are found in which the ectoplasts still retain their semi-permeability though their tonoplasts are torn and their cytoplasmic layers are mixed with vacuolar content (see plate 1, 2 ref. 2) However, such abnormal cells are easily distinguishable from the normal by their appearance. Thus, in the parenchyma cells in twigs of woody plants, unlike the case of onion cells, it may be possible to determine the relative degree of viability in parenchyma cells, upon the basis of both their vital staining with neutral red solution and the appearance of plasmolysed cells, at least in one and the same series of experiments. However, judging[3] of the intactness of twig as a whole cannot be made only on the basis of plasmolysis test in parenchyma cells just subsequent to, or even after, many days of thawing, because inner cortex, pith ray, and pith periclinal tissue are less resistant to freezing than parenchyma cells of cortex. Accordingly, to demonstrate the intactness of a treated twig as a whole, it was planted in moist sand and its capacity tested to continue normal development at least for three months after planting, as mentioned in my reports[4]. Even in the tetrazolium[5] test used by Parker, it may be said that judging the intactness in plants means only determination of a relative value of viability of certain tissues in twig or leaf without testing the whole of it as is done by the plasmolysis method.

In my previous communication in *Nature* (and ref. 4) it was stated that almost all the easily freezable water in a cell may be drawn from the cell interior by extracellular freezing at about −30° C., and that the cells and tissues in this state are not injured even when immersed directly in liquid nitrogen, provided they can sufficiently withstand such pre-freezing at −30° C. Moreover, it was reported that below this temperature the intensity of cold seems not to exert any important effect upon woody plants, at least as long as the intense cold does not extend over a long period. Against this view, Parker has pointed out that one gains the impression from my article that if a plant can be cooled to −30° C. without damage, it can be cooled down far below this without any damage. As a result of Parker's experiment the winter resistance of several conifers could range all the way from a few degrees below freezing to below −190° C.

In the pre-freezing method, to cool plant material to −30° C. does not mean that the temperature of the material only reaches −30° C., but that its material attains at least the state of equilibrium at −30° C. and the state in which almost all the easily freezable water in a cell is drawn from the cell interior. To assure this condition, in the case of freezing in comparatively large material as a twig, I pre-froze it for 16 hr. (overnight) in all cases as mentioned in previous papers[4,5]. In the cooling method used by Parker, when a certain temperature-level was reached in the flask containing a shoot from branch, the flask was removed from the chilling apparatus, then rewarmed. In such cooling method, even if plant material is cooled to −30° C., it is doubtful whether almost all the freezable water in the cell interior can be drawn out or not within such short period of time.

The grade of frost resistance of a woody plant differs according to the manner in which it is estimated. If the grade of frost-resistance is represented by the lowest temperature at which the twigs are able to survive freezing for an hour, especially when the cooling-rate in a temperature-range below −30° C. is comparatively slow as 4 deg. C./hr., there can be found fairly great differences in the grade of frost injury in the twigs treated at an arbitrary different temperature below −30° C. This is particularly the case of less hardy species. However, when the grade of frost resistance is represented by the minimum temperature at which the twigs are able to survive freezing for a full day, there is found, in many cases, scarcely any difference in the grade of frost resistance between the material treated at −30° C. and that at −70° C. (ref. 7). It may be said, therefore, that the discrepancy between our two points of view is due mainly to the difference in the manner of representation of the grade of frost resistance. However, to clarify this problem, it seems necessary to continue further work in many woody plants.

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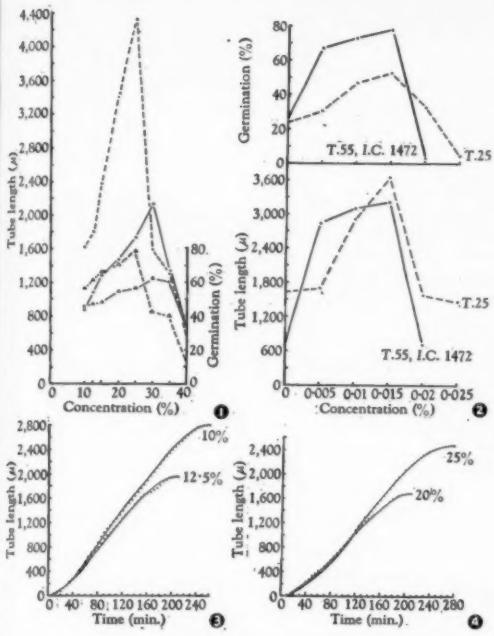
Pollen Germination in some Gramineae: *Pennisetum typhoideum*

Pollen of grasses is notoriously difficult to culture, and even in Nature fertilization usually fails if pollen is not transferred directly from the anthers to the stigma[1,2]. Several previous attempts to germinate the pollen grains of the Gramineae have been unsuccessful[1-6]. In this laboratory attempts were made to germinate pollen grains of *Pennisetum typhoideum* (varieties *T*.25 and *T*.55, *I.C*.1472), *Zea mays* (*T*.41 var. Kanpur) and several varieties of *Hordeum vulgare*, *Sorghum vulgare* and *Triticum aestivum* by the hanging-drop technique (for details of technique see Vasil[7]). Best germination was obtained in *Pennisetum typhoideum*, while in the remaining plants pollen tubes longer than 600μ could not be obtained even after the addition of hormones, vitamins, mineral salts and stylar and ovarian extracts.

The pollen grains of *P. typhoideum T*.25 germinate within 10 min. of their inoculation in 10–40 per cent sucrose solutions and the optimum germination (62 per cent) occurs in 30 per cent sucrose where the tubes attain a length of 2,132μ (Fig. 1). With the addition of 0·01 per cent boric acid best growth is obtained in 25 per cent sucrose. In this medium 78 per cent of the grains germinate and the pollen tubes attain a length of 4,320μ (Fig. 1). Pollen grains of the variety *T*.55, *I.C*.1472 require lower concentrations of sugar: in 12·5 per cent sucrose there is 40 per cent germination and the tubes are 316μ long. Here also the percentage of germination is improved on the addition of 0·01 per cent boric acid, and



Figs. 1–4. *Pennisetum typhoideum*. Fig. 1, variety *T*.25, pollen germination and growth of tubes in different concentrations of sucrose supplemented with 0·01 per cent boric acid; for 3 hr. at 30° C. (——, without boric acid; – – –, with boric acid; ●, tube length; ▲, per cent germination). Fig. 2, varieties *T*.25 and *T*.55, *I.C*.1472, pollen germination and pollen tube growth in 25 per cent (*T*.25) and 12·5 per cent (*T*.55, *I.C*.1472) sucrose supplemented with different concentrations of boric acid; for 4 hr. at 29° C. Fig. 3, variety *T*.55, *I.C*.1472, growth curves of pollen tubes cultured in 10 and 12·5 per cent sucrose supplemented with 0·01 per cent boric acid; at 22° C. Fig. 4, variety *T*.25, same as in Fig. 3 but in 20 and 25 per cent sucrose with 0·01 per cent boric acid; at 18° C.

increases to 76 per cent while the tubes elongate to 3,125μ. The pollen tubes exhibit typical sigmoid growth curves (Figs. 3 and 4).

Among the various sugars tested, sucrose proved to be the best. In dextrose (with 0·015 per cent boric acid) the percentage of germination is 82, a figure higher than that in sucrose, but the length of the tubes is only 2,160μ.

The effect of boric acid is well marked in both the varieties (Fig. 2). In the pollen of *T*.55, *I.C*.1472, a concentration of 0·015 per cent boric acid with 12·5 per cent sucrose gives the best results (78 per cent germination and 3,216μ long pollen tubes). Higher concentrations prove toxic, and 0·02 per cent boric acid brings down the germination to less than 5 per cent and the tube-length to 702μ. Similarly, in the variety *T*.25, a concentration of 0·015 per cent boric acid with 25 per cent sucrose gives 53 per cent germination and 3,636-μ long tubes. Here satisfactory germination occurs with even 0·02 per cent boric acid, but concentrations higher than this cause a marked inhibition of germination as well as tube growth.

The pollen tubes grow very rapidly, show a high rate of protoplasmic streaming and attain a length of about 4,000μ or more during 2–4 hr. growth *in vitro*. Callose plugs develop frequently in the tubes, and in abnormal cases branching tubes were also recorded. Swelling of the pollen-tube tips and other morphological abnormalities are observed at higher temperatures and in supra-optimal concentrations of sucrose and boric acid.

To the best of my knowledge, this is the first report of a successful germination of the pollen of Gramineae *in vitro*. The length of pollen tube obtained here (4,320μ) is similar to that required to affect fertilization in Nature. The present work once again proves the vital and useful part played by boron in pollen germination and pollen tube growth.

I am grateful to Prof. P. Maheshwari and Dr. B. M. Johri for advice and encouragement.

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Toxicity of Gibberellin to Seedless and Seeded Varieties of *Vitis vinifera*

Experiments in 1957 at the University of California showed that gibberellic acid (hereinafter referred to as gibberellin) affected set of fruit, berry size, elongation of cluster parts, fruit composition, and vegetative growth of grapes[1,2]. In the spring of 1958 delayed foliation and dead buds were noted on certain seeded varieties that had received high concentrations in 1957. Observations were therefore continued for two more seasons to determine the damage and to see whether production would return to normal.

The five seeded varieties, being similar in response, are represented here by Red Malaga, various vines of which were sprayed in 1957 with gibberellin at one of three stages (pre-bloom, full-bloom, and after berry shatter). Shoots and clusters were counted in April of 1958 and 1959, and crop weights were measured in September or October. Since the results were essentially alike, regardless of spray date, only the full-bloom spraying is represented here (Table 1). Gibberellin applied in 1957 decreased the shoot and cluster count in 1958 on vines that received 25 p.p.m., and significantly decreased crop weight on vines that received 5 or 25 p.p.m. By 1959, however, recovery was complete. A good yield in 1959 on vines that received 25 p.p.m. in 1957 was probably a result of the low crop in 1958. Thus, injured vines had recovered within two seasons.

The seedless varieties used were Thompson Seedless (Sultanina) and Black Corinth. On June 10, 1957

Table 1. Response of Red Malaga Grapes to Various Concentrations of Gibberellin Sprays applied on June 4, 1957

Concentration of gibberellin (p.p.m.)	Shoot count (No. per vine)		Cluster count (No. per vine)		Crop weight (lb. per vine)	
	1958	1959	1958	1959	1958	1959
0	26·8	22·0	19	13	30·2	16·3
0·1	24·3	27·0	19	16	27·9	18·9
1	22·8	24·0	17	12	24·9	12·3
5	20·3	21·0	16	8	12·4	11·8
25	2·0	24·0	0	18	3·6	24·0
d 0·05	5·3	N.S.	3·9	N.S.	8·5	4·0

(after berry shatter), Thompson Seedless vines, four per treatment, were sprayed with gibberellin at 0, 5, 20, or 50 p.p.m. The same vines were similarly sprayed in 1958 and 1959 at the same physiological stage of development. Table 2 shows the harvest results for 1957 and 1959. Gibberellin at 20 and 50 p.p.m. produced greatly enlarged berries in 1958 but had much less effect in 1959, probably because the crop was unusually heavy. The percentage of total soluble solids (degrees Balling) in 1959 was typical of other years. This experiment shows that gibberellin is non-toxic to Thompson Seedless grapes.

Table 2. Response of Thompson Seedless Grapes to Various Concentrations of Gibberellin Sprays applied in June 1957

Concentration of gibberellin (p.p.m.)	Average weight fruit per vine (lb.) 1959	Average weight per berry (gm.) 1957	1959	Degrees Balling 1957	1959
0	19·5	1·59	2·30	22·4	22·2
5	32·1	1·91	2·62	23·2	22·6
20	37·1	2·71	2·89	18·9	21·4
50	44·3	3·15	2·59	17·6	17·3
d 0·05		0·13		0·7	

One Thompson Seedless and one Black Corinth vine, sprayed after flowering in two consecutive years, showed no visible injury from 1,000 p.p.m. and 100 p.p.m., respectively. Thus, high concentrations are non-toxic to the seedless varieties although far lower concentrations are highly toxic to the seeded varieties studied. A generalization must await tests with more varieties.

The difference between seeded and seedless grapes in sensitivity to gibberellin probably relates to differences previously noted[3,4]. Girdling shortly after flowering greatly enlarges seedless grapes but has little effect on seeded varieties[3]. Thinning, in contrast, ordinarily increases berry size in seeded grapes but not much in seedless grapes[4]. Gibberellin increases size of seedless fruit, but has little or no effect on seeded grapes. It is interesting, therefore, that natural gibberellins have been found in seedless, but not in seeded, varieties[5].

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ENTOMOLOGY

Breeding of the Rabbit Flea, *Spilopsyllus cuniculi* (Dale): Requirement of a 'Factor' from a Pregnant Rabbit for Ovarian Maturation

A study of the biology of the European rabbit-flea (*Spilopsyllus cuniculi*) was commenced by this department when it became apparent that it was an important vector of myxomatosis in Great Britain. A technique for the laboratory culture of the flea was required, but was not rapidly forthcoming. It was repeatedly found that fleas released on domestic or wild rabbits kept in various types of hutches failed to produce eggs. However, Miriam Rothschild[1] reported that the flea bred when rabbits were kept under semi-natural conditions in an outdoor enclosure, and with her encouragement a study was made of ovarian development in the flea (Mead-Briggs, A. R., unpublished work).

Recently we found that if the fleas were placed on pregnant does the ovaries of the fleas matured and eggs were laid in the nest shortly after the young were born, whereas the ovaries of fleas kept on non-pregnant rabbits did not develop. In one experiment to follow the maturation of the ovaries up to ovulation, thirty-five female and twenty-five male virgin fleas were released on each of four rabbits housed in similar two-compartment hutches, one compartment being dark for nesting. The rabbits were: (1) a non-pregnant adult doe; (2) a doe pregnant 1–2 days; (3) a doe pregnant 11 days; (4) a doe pregnant 20 days. Samples of three female fleas were removed periodically (after a minimum of 10 days on the rabbits), and the reproductive systems dissected out. The degree of development of the ovaries was assessed by measurement of the length of the proximal oocyte follicle in one of the ovarioles. (In one individual there is little variation in this dimension between the several ovarioles until shortly before ovulation; then the final stage of egg maturation and subsequent ovulation occurs in only half the ovarioles at a time (Mead-Briggs, A. R., unpublished work).)

The results for fleas from rabbits 1 and 2 are shown in Fig. 1, each point being a mean obtained from the measurement of three dissected specimens. The absence of change in size (from that of immaturity) of the first oocyte follicle of the fleas kept for up to 28 days on the non-pregnant rabbit is contrasted with the increase occurring among fleas fed on the pregnant rabbit.

The rate and period of growth of the ovaries of the fleas fed on the three pregnant rabbits is indicated in Fig. 2. Maximum development is reached at the time of parturition when the fleas immediately leave the adult and are to be found only in the nest or on the nestlings. Development of the ovaries appears to commence about 10 days prior to parturition although the size of the eggs produced may be influenced by

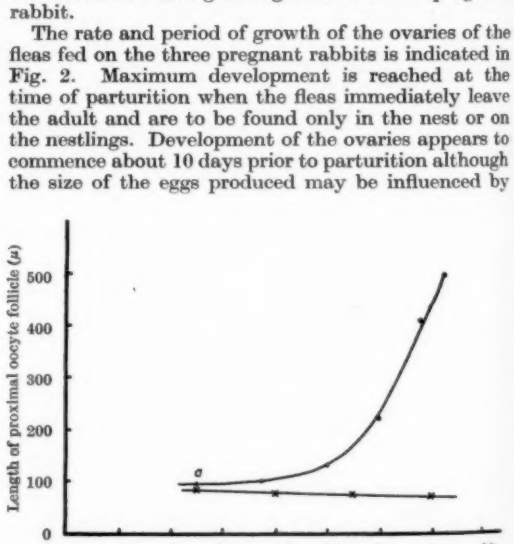

Fig. 1. Development of proximal oocyte follicle of fleas fed on pregnant and non-pregnant rabbits. Point *a* corresponds to the eleventh day of pregnancy. ●, Fleas from rabbit 2; ×, fleas from rabbit 1

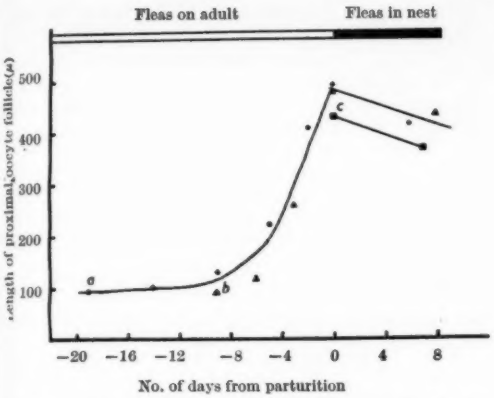

Fig. 2. Development of proximal oocyte follicle of flea related to time of parturition by host. Points *a*, *b* and *c* correspond to stage of development after 10 days feeding on respective rabbit. ●, Fleas from rabbit 2; ▲, fleas from rabbit 3; ■, fleas from rabbit 4

the feeding life of the flea. Thus fleas from rabbit 4 which could only feed for 10 days before commencing egg laying had relatively small eggs (although they were fully fertile) compared with fleas that fed for 19 and 29 days (rabbits 3 and 2 respectively).

At present the nature of the factor initiating ovarian development of the fleas fed on pregnant does is uncertain. Various controls have precluded it being related to nest-building habits by the pregnant rabbits. A likely hypothesis is that it is a factor, perhaps nutritional, present only in the blood of a pregnant rabbit and perhaps only at the required level during the later stages of pregnancy. Buxton[2] compared the production of eggs by *Xenopsylla cheopis* when fed on baby and adult mice and found that with the baby mice eggs were produced in smaller numbers and only after an unusual delay. He suggested this might result from the lack of mammalian sex hormones normally obtained in the blood of adult mice.

Wigglesworth[3] has shown that in a number of blood-sucking arthropods a small amount of hæmoglobin is absorbed into the hæmolymph without digestion, and some of this hæmoglobin is transferred with little change to the yolk of the developing eggs. He concluded that some of the normal protein constituents of egg yolk may perhaps be formed elsewhere in the insect body and merely transmitted to the yolk via the follicle cells and not synthesized in them. This could be the case in fleas which have simple, panoistic ovarioles lacking any trophic tissue other than the follicle epithelium. While flea eggs do not contain any pigmented hæmoglobin derivatives, variation in the serum proteins of the host could be important. Hence, in the present case, it may be significant that Brambell *et al.*[4] found marked differences between the sera of non-pregnant, adult rabbits and rabbits 25 days pregnant, both in respect of the total protein concentration and in the proportions of the components.

So far as we are aware *Spilopsyllus cuniculi* is the only flea shown to require a pregnant host for egg maturation, but failures to breed a few species of flea in captivity may indicate others have similar requirements. The most important result of this mechanism which produces perfect synchronization between maturation of eggs by the flea parasite and parturition by the host is that the eggs are immediately ready to be laid in a microclimate ideal for further development provided by the rabbits' breeding nest.

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Experimental Breeding of *Anopheles gambiae* Giles in Papyrus Swamps

In Uganda, *Anopheles gambiae* Giles does not breed in the interior of papyrus swamps, in their natural, undisturbed state. But a considerable amount of breeding may occur at the periphery, outside the papyrus zone, particularly in hoof-prints, cattle-drinking places, and open natural pools[1]. Also, where papyrus swamps have been drained and the land used for cultivating such crops as *Colocasia*, larvæ may be found in the shallow, sunlit pools between cultivation-mounds. On the whole, the swamps are not a potent source of malaria[2].

The composition and nature of the breeding water have a twofold influence on the mosquito, affecting not only the larvæ present in the water, but also the gravid adult female looking for a place to deposit its eggs[3]. However, although it seems quite clear that the ecological distribution of larvæ in Nature is largely a result of the different oviposition habits of the adult mosquito[4], it is also generally accepted that the absence of mosquito larvæ from a particular breeding place admits of two alternative interpretations: either (*a*) the females do not oviposit there at all; or (*b*) they do rather indiscriminately and that larvæ will develop in certain types of water and not in others. The preliminary observations reported in this communication were made to investigate alternative (*b*), that is, whether the absence of *A. gambiae* larvæ from the interior of papyrus swamps, in Uganda, is because they cannot develop in such habitats.

The observations were made in two papyrus swamps near Kampala. Cages made of nylon gauze or from iron drums were planted in the swamps. All predators were removed or prevented from entering the cages. This made the breeding conditions less natural; but it excludes the factor of predators from consideration of the results. Larvæ of *A. gambiae*, in various stages of development, were then placed in swamp water, in the cages, and all adults emerging afterwards were recorded and removed. The results of seven experiments are summarized in Table 1. Experiments 1 and 3 were made at the periphery of the swamp, just outside the papyrus zone; 5, just inside the papyrus zone; 4, 6 and 11, inside the swamp among tall papyrus and under considerable shade; and 10, inside the swamp, but in an exposed previously cut papyrus area.

Table 1 shows that 93·7 per cent of the 1,120 *A. gambiae* larvæ introduced into the papyrus swamps

Table 1. Recovery of Adult *Anopheles gambiae* Giles from Larvæ placed in Papyrus Swamps

Exp. No.	No. and stage (in brackets) of larvæ	Days since larvæ were placed in swamp		Total of adults emerged	
		First adult emergence	Last adult emergence	No.	Per-centage
1	140 (I, II, III, IV)	3	20	30	21·4
3	100 (I)	26	28	3	3·0
4	140 (I, II, III, IV)	4		1	0·7
5	140 (I, II, III, IV)	3	23	7	5·0
6	200 (I, II, III, IV)	3	8	12	6·0
10	200 (IV)	3	9	10	5·0
11	200 (IV)	5	8	7	3·5

Totals: Larvæ, 1,120; adults emerged, 70, that is, 6·3 per cent. (N.B. In column 2, the numbers are totals of all the respective stages shown.)

did not complete their development to the adult stage. The detailed records indicate a very high mortality among the early stages. Generally, it would thus seem that the interior of papyrus swamps is extremely unfavourable for the development of *A. gambiae* larvæ. Also, the duration of the larva–adult period appeared to be considerably longer than one usually finds in the favoured natural breeding places.

The water in papyrus swamps is characterized by a very high degree of organic pollution and by extreme deoxygenation[5,6]. It has been suggested that suitable larval food is absent from swamp waters[7] and that the middle of the swamp does not provide breeding facilities for *A. gambiae*, owing to the high degree of organic pollution of the water which obtains there[1]. Several authors have directed attention to the absence of larvæ from water with large organic content[8]; although Harvey and Symes[9] report to the contrary. It is also known that *A. gambiae* may tolerate a considerable degree of animal pollution, but it is very sensitive to organic pollution of vegetable origin[3]. Pollution in papyrus swamps is caused by decaying vegetation, and *A. gambiae* would thus be very sensitive to it. The view that an increase in the proportion of organic matter in natural breeding-places slows down the development of *A. gambiae* larvæ[10] is supported by the present observations. But, how far the predominantly anaerobic conditions of the swamp waters affected the results of our observations is not very clear. Since the larvæ depend on atmospheric air and are not forcibly prevented from periodically rising to the surface to breathe, lack of oxygen in the medium is not a respiratory problem. But it can influence the length of time during which the larvæ are submerged and this seems to be ecologically important.

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Taxonomic Significance of Spermathecal Structure in Some Species of *Tribolium*

Recent examination of spermathecæ in tenebrionid beetles associated with stored products has revealed that there are two distinct types of structure which are termed here the 'tenebrio' type and the 'chamber' type. Their basic plan and relationship to the rest of the female reproductive system are similar; but there are certain differences which, in regard to the genus *Tribolium*, are considered to be of some phylogenetic significance. In both types, a duct of varying width and length, which terminates in the main sperm storage region, arises from the common oviduct. In *Tenebrio molitor* this duct is short and wide and ends in a group of convoluted, thin-walled tubes bound together by a tough membrane. Arising from their common base is a single, longer structure which may be glandular, having large-celled walls and a restricted lumen. Dissection of fertilized females has shown that the convoluted tubes carry sperm. In the chamber type, found in *Gnathocerus*, *Alphitobius*, *Alphitophagus* and some *Tribolium* species, there is a similar duct which runs to a strongly chitinized chamber in which motile spermatozoa are easily detected. This is variously shaped and arising either from the end opposite the duct entrance or from the side is a more-or-less elongate glandular region. In *Palorus* species this basic pattern is modified, associated with a muscular bursa.

The genus *Tribolium* has been divided on external morphological features into five species groups, namely, *brevicornis*, *confusum*, *alcine*, *castaneum* and *myrmecophilum*, associated with the following geographical regions, America, Africa, Madagascar, Indo-Australia and the Malay peninsula and East Indies respectively[1]. The spermathecæ of five species from the *castaneum* and *confusum* groups have recently been examined in some detail, and it was found that the structure in *T. castaneum* and *madens* (*castaneum* group) closely resembled that of *Tenebrio* whereas *T. confusum*, *anaphe* and *destructor* (*confusum* group) had the more common chamber type of spermatheca. In the former species the duct was very short, terminating in a number of long, convoluted tubes invested in a tough, elastic membrane. These tubes were found to contain spermatozoa. Connected to the common base of the tubes by a chitinized collar was a short, glandular region. In the latter species the duct was again short and wide, but terminated in a junction, one arm of which entered a strongly chitinized S-shaped chamber, while the other arm ran into a glandular region which was long in *anaphe* and *destructor* but shorter in *confusum*.

The present evidence supports the maintenance of the *confusum* (African) and *castaneum* (Indo-Australian) groups while further work is required to indicate similar associations between the other species groups mentioned here. Also, with regard to the suggestion that *T. molitor* and *obscurus* originated in Europe or Asia and were only later transported to Africa and America[2], possible affinities between the *castaneum* group and *tenebrio* species, and the evolutionary significance of the structures described here, must be considered.

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FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, September 26

OLIVER BIRD TRUST; BRITISH SOCIETY FOR IMMUNOLOGY; and the SOCIETY FOR THE STUDY OF FERTILITY (in the Large Lecture Theatre, London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), at 5 p.m.—Dr. Albert Tyler (California Institute of Technology): "Immunological Approaches to Fertility Control" (Fourth Oliver Bird Lecture).*

SOCIETY OF CHEMICAL INDUSTRY, PESTICIDES GROUP (at 14 Belgrave Square, London, S.W.1), at 5.30 p.m.—Dr. E. H. Colhoun: "Interpretations of Insecticidal Action".

Tuesday, September 27—Thursday, September 29

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH (at the Connaught Rooms, Great Queen Street, London, W.C.2), at 10 a.m. daily—Conference on "Ergonomics in Industry".

Wednesday, September 28

BRITISH INSTITUTION OF RADIO ENGINEERS (at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1), at 6.30 p.m.—Discussion on "The Land Colour Theory with Particular Reference to its Applications to Colour Television".

OIL AND COLOUR CHEMISTS' ASSOCIATION (at the Royal Society of Tropical Medicine and Hygiene, 26 Portland Place, London, W.1), at 7 p.m.—Mr. W. F. Jenkins, Mr. A. Mott and Dr. R. J. Wicker: "Unsaturated Polyesters for Surface Coatings".

SOCIETY FOR PSYCHICAL RESEARCH (in the Court Room, Caxton Hall, London, S.W.1), at 7 p.m.—Dr. W. Grey Walter: "Neurophysiological Aspects of Hallucinations and Illusory Experiences" (Myers Memorial Lecture)*.

Thursday, September 29—Friday, September 30

WORSHIPFUL SOCIETY OF APOTHECARIES OF LONDON, FACULTY OF THE HISTORY OF MEDICINE AND PHARMACY (at Apothecaries Hall, Black Friars Lane, London, E.C.4 (mornings), the Royal Society of Medicine, 1 Wimpole Street, London, W.1, on Thursday afternoon, and at the Royal College of Physicians, Pall Mall East, London, S.W.1, on Friday afternoon)—First British Congress on the History of Medicine and Pharmacy.

SOCIETY OF CHEMICAL INDUSTRY, SURFACE ACTIVITY GROUP (at the Royal Institution, 21 Albemarle Street, London, W.1)—Symposium on "Powders in Industry—Properties and Principles of Application".

Saturday, October 1

ASSOCIATION OF CLINICAL BIOCHEMISTS (joint meeting with the ASSOCIATION OF CLINICAL PATHOLOGISTS, at the Royal College of Surgeons, Lincoln's Inn Fields, London, W.C.2), at 9.30 a.m.—Annual General Meeting and Symposium on "Malabsorption".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

SENIOR TECHNICAL ASSISTANT (with experience in the use of transistors, and preferably familiar with nuclear instrumentation) IN THE PHYSICS DEPARTMENT, to help in the design and construction of electronic and other instruments to be used in artificial Earth satellites—The Secretary and Registrar, The University, Southampton (September 28).

ASSISTANT LECTURER, Grade II (with a good honours degree) IN THE DEPARTMENT OF PURE AND APPLIED PHYSICS, to teach up to degree level—The Registrar, Royal Technical College, Salford 5, Lancs (September 30).

PLANT PHYSIOLOGIST (with a good honours degree in botany and research experience), for investigation of effects of temperature, oxygen and carbon dioxide on the respiration of apples—The Director, Ditton Laboratory, Agricultural Research Council, Larkfield, Maidstone, Kent (September 30).

LECTURER (with an honours degree, and preferably with a higher degree in chemistry with postgraduate experience of academic or industrial research) IN PHYSICAL CHEMISTRY—The Secretary, Sir John Cass College, Jewry Street, London, E.C.3 (October 1).

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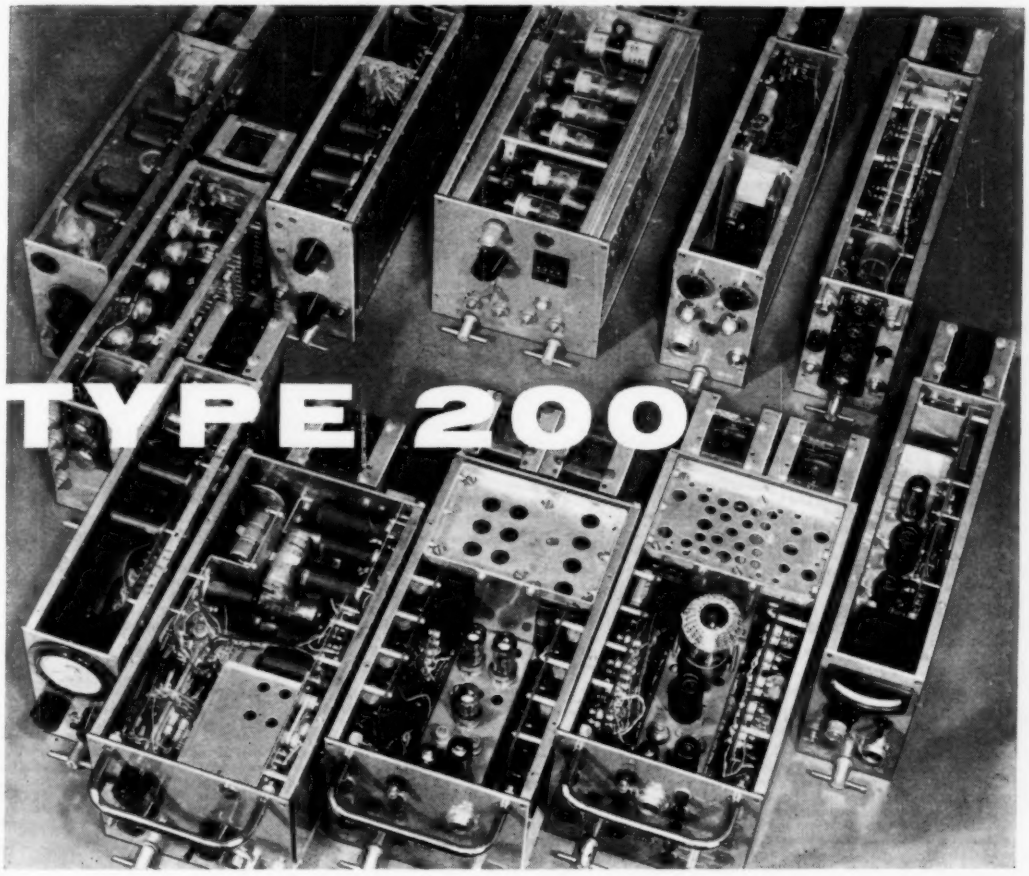

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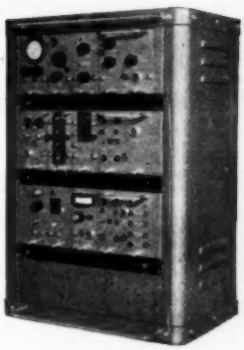

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